OECD WGRISK – ONGOING TASKS AND POTENTIAL FUTURE ACTIVITIES

Marina Röwekamp[1], Kevin Coyne[2], Vinh N. Dang[3], Yolande Akl[4], Jeanne-Marie Lanore[5]

[1] *Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH: Schwertnergasse 1, 50667 Köln, Germany, Marina.Roewekamp@grs.de*
[2] *United States Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research: MS TWFN 10A12 Washington, DC 20555-0001, USA, Kevin.Coyne@nrc.gov*
[3] *Paul Scherrer Institute (PSI): CH-5232 Villigen, Switzerland, vinh.dang@psi.ch*
[4] *Canadian Nuclear Safety Commission (CNSC): 280 Slater Street, P.O.Box 1046 - Station B, Ottawa, Ontario K1P 5S9, Canada, yolande.akl@canada.ca*
[5] *Institut de Radioprotection et de Sûreté Nucléaire (IRSN): B.P. N°17 92262 Fontenay-aux-Roses Cedex, France, jeanne-marie.lanore-cespi@irsn.fr*

The OECD/NEA/CSNI Working Group on Risk Assessment (WGRISK) has a goal to continuously enhance the understanding of probabilistic risk assessment (PRA[1]) and to facilitate the use and application of probabilistic approaches as a tool for nuclear safety assessment. WGRISK is supported by over twenty member countries to exchange risk related information between experts and to advance the use of PRA for improving safety. This paper describes the WGRISK program of work and covers recently completed and ongoing work. WGRISK recently completed a task on "Probabilistic Safety Assessment Insights Relating to the Loss of Electrical Sources". In addition, WGRISK has four ongoing tasks:

- *"Human Reliability Analysis in External Events PSA – Survey of Methods and Practice",*
- *"Status of Site Level PSA (Including Multi-unit PSA) Developments",*
- *"Status of Practice for Level 3 PSA", and*
- *"PSA Use and Development in Member and Non-member Countries".*

WGRISK maintains an active program of work and is also considering future tasks on probabilistic risk analyses for research reactors, the treatment of digital I&C in risk analyses, risk assessment for the spent fuel pool, and PSA for harsh weather conditions.

I. INTRODUCTION

The OECD Nuclear Energy Agency (NEA) Committee on the Safety of Nuclear Installations (CSNI), in close conjunction with the Committee on Nuclear Regulatory Activities (CNRA), maintains a joint trategic plan and mandates (Ref. 1) in order to identify main challenges and focus areas. One important challenge identified in this CSNI/CNRA Strategic Plan is the safe operation of current, new, and advanced nuclear facilities, including improving the use of risk-informed regulatory strategies, updated with operating experience and safety research results, to evaluate, measure, and enhance the safety performance of nuclear installations.

The CSNI Working Group on Risk Assessment (WGRISK) has the overall goal of continuously enhancing the understanding of probabilistic risk assessment (PRA, synonymously used for PSA) and facilitating use and application of probabilistic approaches as a tool for nuclear safety assessment. In support of this goal, WGRISK carries out various activities to exchange risk related information between experts in member countries and to advance the use of these tools for improving safety.

[1] In this paper, the terms *Probabilistic Risk Assessment* (PRA) and *Probabilistic Safety Assessment* (PSA) are used interchangeably.

This paper presents a brief overview of the recent work of WGRISK covering ongoing or recently finished activities (hereafter called "*tasks*") and perspectives, e.g. the recommendations resulting from these tasks. The following different WGRISK activities (so called tasks) have either been recently completed or are ongoing:

- The task 2013(1) "Probabilistic Safety Assessment Insights Relating to the Loss of Electrical Sources" initiated in June 2013 has been completed in spring 2016. The insights address safety improvements related to PSA results and applications as well as PSA methodology issues.
- The task 2014(1) "Human Reliability Analysis in External Events PSA – Survey of Methods and Practice" was started in 2015 to develop and analyze the results of a questionnaire survey on the methods and analysis practices used in existing PSAs for external event initiators.
- The task 2015(1) "Status of Site Level PSA (Including Multi-unit PSA) Developments" started in summer 2015 aiming on exchanging information, how multi-unit multi-source issues are addressed in risk assessment.
- The task 2015(2) "Status of Practice for Level 3 PSA" is to identify best practices for the conduct of Level 3 PSA for nuclear power plants and will be accomplished through the use of a focused survey questionnaire to gather information on the current state of practice in member and observer countries as well as to solicit views on several challenging technical areas.
- The task 2015(3) "PSA Use and Development in Member and Non-member Countries" started in late 2015 is a regular update prepared approximately every five years. This report will present the status of PSA developments and applications and shall particularly focus on lessons learned from post-Fukushima investigations and effects on the PSA.

II. RECENTLY COMPLETED ACTIVITIES

Recently, one WGRISK task has been completed associated with risk insights for losses of electrical power sources. The loss of electrical power sources2 is generally recognized as an important contributor to the risk related to nuclear power plants. In particular, the importance of external hazards leading to a loss of electrical power sources (external and/or internal to the nuclear plant) has been further underscored by the Fukushima Dai-ichi reactor accidents.

The WGRISK determined that a review of current PSA studies would be a useful method to identify safety insights associated with losses of electrical power sources. More precisely two types of risk and safety insights were sought:

- Insights for plant safety related to results and applications of risk calculations:
  This includes insights related to the overall risk of losses of power sources relative to other contributions, potentially safety weaknesses, the balance between core damage prevention and mitigation, comparison between internal initiating events and hazards, key sources of uncertainty, and safety benefits brought by modifications already implemented or planned (including possible post-Fukushima modifications).
- Insights on PSA methodology:
  This includes insights related to the identification of good practices, potential methodology gaps, and differences in the methodologies used or developed by member countries.

Information was collected via surveys provided to WGRISK member and observer countries. In total, the questionnaire responses covered 38 PSA studies from 19 countries. Based on the analysis of questionnaire responses, the following insights were identified:

- With regard to initiating events, the following conclusions can be drawn from PSA information in the questionnaire responses:
  - In most cases, various categories of power supply faults were analyzed, as opposed to analyzing only a single category of failures in electric power supply sources. For example, some responders identified long- or short-term loss of offsite power (LOOP) categories rather than combining all LOOP events into a single category.
  - The duration of a power supply fault influences accident mitigation features and the corresponding accident sequence frequencies. Accordingly, the duration of a LOOP was taken into consideration in most analyses.
  - External hazards as LOOP initiators were considered in most of the analyses addressed in the survey. It appears to be a common practice to model the effects of external hazards on the power supply system as separate initiating events unless LOOP is the only adverse consequence of the hazard.

[2] The term "electrical power sources" is equivalent to the term "electrical supplies" as used in IAEA documents (Ref. 2).

- The initiating events considered are site specific and grouped differently. However a global LOOP frequency is in the range of some 10^{-1}/year to 10^{-3}/year for all the responding countries.
- Plant-, site-, region- or country-specific data were used to estimate initiating event frequencies in most cases. There are dedicated data collection and analysis programs in place in a number of member countries to support the estimation.

The following conclusions can be drawn from PSA information on modelling and data given in the questionnaire responses:

- Power recovery is important for both the initiating event definition and event sequence development. Recovery was modelled in the majority of the PSAs covered by the survey. Multiple recovery times were usually taken into account.
- Various kinds of recovery models were applied depending on the initiating events, the availability of operational experience, and the analysis approach used.
- Usually, the failure to start and the failure to continue running failure modes of active alternate power supply equipment (mostly Diesel generators but also including other power sources, as appropriate) were considered in the accident sequence models.
- Some analyses included a detailed fault tree modelling of Diesel generators and other sources of electric power supply.
- Failures of bus bars and batteries are typically modelled.
- Common cause failures of active power supply equipment (mostly Diesel generators) were taken into consideration.
- The traditional mission time of 24 hours is predominantly used in the accident sequence models for power supply faults. Some responses point out the unnecessary conservatism in using 24 hours of mission time for short-term loss of power events. On the other hand, the automatic use of 24 hours may lead to underestimation of risk from long term scenarios, especially if LOOP and additional power supply failures are induced by external events.
- Due to operational stability problems, less than half of the analyses gave credit to plant operation in house load or island mode following a LOOP event, although most plants have the capability to continue power operation when separated from the electrical grid.

The following main conclusions can be drawn concerning PSA results:

- The core damage frequency (CDF) resulting from LOOP events, when provided in the survey, have a wide variability (10^{-4}/year – 10^{-6}/year), with no particular tendency related to the design.
- Two general observations can be made:
  - The BWR plants included in this survey generally have a lower CDF contribution from LOOP than the PWR plants.
  - The relative CDF contribution from LOOP for the PWR plants included in this survey tends to have a wider variability than the BWR plants.
- Concerning the importance measures of SSCs, a few key insights from the survey include:
  - The relative high reliability of batteries generally results in a lower Fussel-Vesely (FV) importance, but the lack of redundancy for these components results in very high values for Risk Achievement Worth (RAW).
  - Decay heat removal systems such as reactor core isolation cooling and auxiliary feedwater have a relatively low to moderate FV importance, but can have a relatively high RAW value due to limited redundancy for this function.
  - The emergency diesel generators (EDGs) had a somewhat variable importance, but the risk contribution is dominated by common cause failure. The RAW values reported for the EDGs had significant variability, but for some plants the loss of EDGs could be significant risk contributor.

With respect to safety improvements, the following main conclusions can be drawn:

- Although PSA is not the only basis for decision-making, the questionnaire answers indicate that a large number of safety improvements are related to the mitigation of losses of electrical power sources.
- The main safety improvements relate directly to electrical power sources (addition of complementary equipment), but several modifications relate also to mitigation functions impacted by LOOP events.

- Many modifications include mobile equipment or other equipment which needs operator action requiring that human reliability analysis (HRA) model the particular conditions of a LOOP or a SBO.
- Several modifications include equipment shared by several units or interconnections between units. The risk benefit estimation in these cases requires a multi-unit assessment.
- Although many improvements appear as "initiator neutral", several improvements are protected against specific external hazards (e.g., earthquake, flooding, high winds). A technically adequate PSA analysis of LOOP makes it possible to identify specific strategies for coping with external hazards.

Concerning the conclusions for LOOP modelling in PSA, seven important challenges were identified based on the responses to the questionnaire:

- LOOP frequency data analysis related to common cause failure (CCF),
- timing of accident sequence development in LOOP event trees,
- determination of the proper mission time for LOOP initiating event (IE) modelling,
- determination of the specific off-site grid recovery times and probabilities,
- credibility of reactor coolant pump (RCP) seal integrity,
- interaction between units at the multi-unit site following LOOP, and
- lack of data to quantify CCFs of bus bars.

The following general conclusions have been drawn:

- This survey shows that challenges related to the plant response to LOOP (i.e. plant recovery from LOOP or from the consequent blackout) can be key contributors in PSA so particular attention needs to be paid to them. The insights related to the plant response are more generic and consequently more interesting for exchange of knowledge and of good practices than initiating events frequencies which are very site specific.
- The following recommendations for improvement of PSA modelling are proposed based on the survey:
  - The proper reliability data collection for plant power supply components which would include repair or recovery times and CCF events. The criteria (conditions) for repair/recovery success need to be properly defined.
  - The proper input data determination and collection to determine the LOOP frequencies and probabilities of external grid recovery failures. It should include grid specific reliability models considering also repair or recovery times and CCF events.
  - The justification of the safe end state for accident sequences and determination of the proper mission time (i.e. time to reach safe state) based on it.
  - The proper modelling of interactions between units of a multi-unit should include the following items:
    - The adverse impact from unavailabilities/initiating events occurred in the other units;
    - The impact of the common initiating events (including hazards) affecting more units;
    - The support from the other units (e.g. utilization of equipment, cross-connections, etc. from the other units).
  - The proper consideration timing of an accident development including important breakpoints (loss of RCP seal integrity, battery depletion, etc.).
- The survey indicates the importance of ensuring means for recovery, including means for repair and back-up equipment (fixed or mobile) and also all the practical problems relating to the use of this equipment (human capacity, accessibility, strategy and decision making).

These insights can be used within several NEA activities (CNRA, CSNI) as well as in other international or national activities relating to PSA or more generally to safety of nuclear power plants. These insights will be especially useful for the CSNI/WGELEC and CSNI/WGRISK. For example, the WGRISK will use these insights in its program of work: it can be noted that the study of multi-unit interactions is already in progress with the task WGRISK(2015)2 "Status of Site Level PSA (including Multi-unit PSA) Developments" (see below), the issue of HRA under extreme conditions is addressed by the task WGRISK(2014)1 "HRA in External Events PSA – Survey of Methods and Practices", and recent PSA and safety improvements (particularly post-Fukushima actions) will be reviewed in the Task WGRISK(2015)4 "Use and Development of Probabilistic Safety Assessment in Member and Non-member Countries". The final report from this Task (Ref. 3) is in publication and will be publicly available in the near future.

III. ONGOING ACTIVITIES

At the time being, four activities (so-called tasks are ongoing. The status of these tasks is presented in the following.

III.A. Human Reliability Analysis in External Events PSA – Survey of Methods and Practice

The task "Human Reliability Analysis in External Events PSA – Survey of Methods and Practice" was initiated in order to develop and analyze the results of a questionnaire survey on the methods and analysis practices used in existing PSAs for external event initiators focusing on seismic, external flooding, and diverse severe weather initiators. Main objectives are to identify and examine the key assumptions of the analyses and applied methods in order to build consensus and to harmonize human reliability analysis in these PSAs, for a given initiator and across different types of initiators, to the extent that the performance conditions and influences are shared.

Within nuclear industry, there are currently many efforts to initiate, update, or extend the PSAs with regard to modeling the plant response and the risk from external hazards. With few exceptions, the available HRA methods focus on operator actions for Level 1 internal events PSA. Given the diversity of the external hazards under consideration, a potential concern is that specific methods are developed for each hazard initiator, where the differences among the methods may be arbitrary rather than justified by concrete and particular aspects of the hazard. At the same time, a number of the relevant issues that relate to the reliability of human actions are shared among initiators. Some of these include access for ex-control room actions (including damage to plant access routes caused by the hazard), harsh conditions for the performance of these actions, potentially degraded or damaged I&C, and area impacts. These issues represent challenges for HRA, for qualitative as well as quantitative analyses. The objectives of the task are to identify and examine the key assumptions of the analyses and applied methods, with the aim to build consensus and harmonize the HRA in these PSAs, for a given initiator and across different types of initiators, to the extent that the performance conditions and influences are shared.

In a first phase, three types of external hazards have been selected as a focus for the survey. These are earthquakes, diverse severe weather initiators, and external floods. One criterion considered in choosing these is that there is sufficient application experience on which a comparative analysis can subsequently be performed. This comparison would take place on two levels. The first examines the treatment of the issues relevant to a given hazard across different HRAs; one question here whether there is agreement as to which issues are significant. At a second level, the treatment of a given issue is compared across the initiators. A survey questionnaire has been prepared and is being distributed.

III.B. Status of Site Level PSA (Including Multi-unit PSA) Developments

It has been recognized on an international basis that, for nuclear reactor sites consisting of multiple installations with radioactive inventories, a single reactor specific risk metric is not adequate to assess the radiological risk arising from a severe event affecting more than one installation on the site. Following an *International Workshop on Multi-Unit Probabilistic Safety Assessment (PSA)* in November 2014 organized by the Canadian Nuclear Safety Commission (CNSC) identifying several challenges for PSA when considering issues affecting the whole site PSA and indicating the need to address multiple unit issues in safety assessment, WGRISK initiated a corresponding task 2015(1) "Status of Site Level PSA (Including Multi-unit PSA) Developments".

The objective of this task is the collection of information on how multi-unit issues are being addressed in probabilistic assessment of multi-unit site NPPs, on challenges and developments as well as on the actual and intended uses and applications of Site Level PSA[3]. Further challenges and methodological developments of Site Level PSA, including risk metrics and safety goals, as well as potential uses for multi-unit sites safety improvement and management shall be addressed. The status of the task is as follows:

CNSC is the lead for the first phase of this task intended to end in June 2017 with report, followed by a second task phase with the intention to hold a WGRISK workshop on Site Level PSA, probably in November 2017, organized by GRS in Germany.

An initial survey was conducted in 2015 as part of Phase 1 and based on the scope and discussion with the task core group. Three focus areas have been identified:

- Risk aggregation,

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[3] Site Level PSA includes single unit PSA that consider the impact (positive or negative) of the other site units on the accident sequences, fully integrated PSA models that addresses accident sequences that may involve any combination of reactor units and radiological sources, and hybrids of these models.

- Multi-source interactions or dependencies, and
- Risk metrics and safety goals.

CNSC proposed a work program for each of the three focus areas and submitted these to all interested member countries for comments. The progress with respect to the three focus areas is as follows:

- Risk Aggregation:
  A work plan was prepared and distributed on April 21, 2016 to all OECD/WGRISK members identifying the challenges to be addressed on the following:
  - Risk metrics at the unit level;
  - Risk Metrics at the site level;
  - Risk Aggregation methods across different hazard groups and operational modes at the unit level;
  - Risk Aggregation methods across all units and other radioactive sources and operational modes.
- Multi- unit PSA interactions:
  The key challenges identified from the teleconference with core group members are summarized below:
  - Identification of shared systems, structures and components (SSCs) and other type of sharing for the purpose of whole-site PSA;
  - Modelling site level response and interactions/dependencies to the site wide challenges;
  - Modelling site level response (including interactions/dependencies) to a single unit event (accident);
  - HRA modelling for the whole site PSA;
  - Interaction in Level 2 PSA stage, especially the severe accident modelling and simulation for a multi-unit plant;
  - Interaction between reactor core and spent fuel pool or other significant radiological sources on site;
  - Common cause failures (CCFs) modelling across units for the whole site PSA;
  - Uncertainties.
- Risk Metrics and Safety Goals:
  The key challenges identified for this focus area as follows:
  - Consideration of environmental impacts and /or land contamination within the safety goal structure;
  - Consideration of population distribution around the site within the safety goal structure
  - Practical elimination concept for the large radioactive releases;
  - Relationship between safety goals levels:
  - Definition of risk metrics to be used for safety goals.

The work plans have been sent to the members of each focus area group for providing information on the topics mentioned above. CNSC will compile the responses such that insights can be gained and conclusions be drawn commonly by the task group members.

III.C. Best Practices for Level 3 Probabilistic Safety Assessment

Based on feedback from recent WGRISK meetings and information in the report NEA/CSNI/R(2012)11, "Use and Development of Probabilistic Safety Assessment An Overview of the situation at the end of 2010" published in December 2012 (Ref. 4), an increasing number of countries are pursuing development of PSAs that explicitly calculate public health, safety, and economic impacts (Level 3 PSA). Therefore, the objective of this task is to: (1) survey member and observer countries to determine current methodological practices in Level 3 PSA, (2) identify common challenges and notable practices, and (3) summarize the results of this activity in a final task report.

This task will examine a number of challenging issues associated with Level PSA consequence analysis. Examples of issues that will be examined include the following:

- Risk metrics for effectively communicating Level 3 PSA results, including metrics appropriate for capturing multiunit issues;
- Modeling practices, including distance truncation, dose response (linear no-threshold, low dose truncation, etc.), exposure pathways (aquatic, airborne), scenario binning (identifying appropriate plant damage states and release categories), and radiological transport;
- Release truncation time, including consideration of severe accident mitigation and offsite response capability;

- Determination of economic impacts due to property and health impacts, including valuation of life and property impacts, costs associated with emergency preparedness and radiological countermeasures (with emphasis on economic impacts that may influence public safety);
- Consideration of site radiological sources including multiple units, spent fuel, and other sources;
- Communication practices for the public and decision-makers, including use of expected values; frequency/consequence curves; uncertainty quantification; and placing low likelihood events into an understandable context.

A survey questionnaire has been prepared and issued to WGRISK members and observers to gather information on these and other topics. It is anticipated that the task will be completed in 2017 with the final report published later that year.

III.D. PSA Use and Development in Member and Non-member Countries

WGRISK routinely shares information regarding PSA methodologies used to identify nuclear power plant risk contributors and assess their importance as well as applications of PSA results. To this end, WGRISK has periodically summarized the current status of PSA progammes in member and some non-member countries in a PSA "Use and Development" report. This report, intended to be updated every 3 to 5 years to ensure that the content remains timely and relevant, provides descriptions of the current status of PSA programs in member countries, including basic background information, guidelines, various PSA applications, major results in recent studies, PSA based plant modifications and research and development topics. Feedback received by WGRISK indicates that these reports are widely used to benchmark PSA programs and identify emerging trends in PSA developments and applications.

The objective of this task is to update the previous task report published in late 2012 (Ref. 4), with an increased emphasis on new PSA developments and applications, particularly following the Fukushima Dai-ichi accidents. The structure and format of the report will be also enhanced to better communicate information and insights, taking into account also the experience of using the previous versions of the report. The deliverable from this activity will be a final task report providing descriptions of the current status of PSA programs in member and participating non-member countries including basic background information, guidelines, various PSA applications, major results in recent studies, PSA based plant modifications and research and development topics. It is expected that this report will be published in late 2017.

IV. CONCLUSIONS AND OUTLOOK

WGRISK provides timely, high-quality work products addressing the broad range of risk assessment and management needs identified by CSNI and the working group members. It serves as an important resource for risk-related knowledge management activities as well as an internationally recognized, authoritative source on risk-related matters.

The insights of the task "Probabilistic Safety Assessment Insights Relating to the Loss of Electrical Sources" address safety improvements related to PSA results and applications as well as PSA methodology issues. The main conclusions underline the importance of data collection related to loss and recovery of electrical power, timing of accident sequences, and consideration of common cause failures Moreover they account for multi-unit interactions.

The task "Human Reliability Analysis in External Events PSA – Survey of Methods and Practice" was initiated in order to develop and analyze the results of a questionnaire survey on the methods and analysis practices used in existing PSAs for external event initiators focusing on seismic, external flooding, and diverse severe weather initiators. Main objectives are to identify and examine the key assumptions of the analyses and applied methods in order to build consensus and to harmonize human reliability analysis in these PSAs, for a given initiator and across different types of initiators, to the extent that the performance conditions and influences are shared.

A third task "Status of Site Level PSA (Including Multi-unit PSA) Developments" aims on exchanging information, how multi-unit multi-source issues are addressed in risk analyses carried out in member states in order to identify their challenges, and on research/projects for Site Level PSA on-going in member countries. The task has been split in Phase 1: "Survey and Questionnaire on Site Level PSA Developments" to be completed in 2017, followed by Phase 2: "CSNI/WGRISK Site Level PSA Workshop" to be organized by the end of 2017. As part of the first phase of this task, an initial survey was completed in December 2015, and, based on the interest and experience the core group members, this task actually focuses on technical issues and challenges regarding risk metrics, safety goals, risk aggregation and the assessment of multi-source interactions or dependencies relevant to Site Level PSA.

The purpose of a fourth task "Status of Practice for Level 3 PSA" is to identify best practices for the conduct of Level 3 PSA (consequence analysis) for nuclear power plants. This activity will be accomplished through the use of a focused survey questionnaire to gather information on the current state of practice in member and observer countries and to solicit views on several challenging technical areas.

Last, but not least, another update of the report "PSA Use and Development in Member and Non-member Countries" prepared approximately every five years has been recently started. The corresponding report will present the status of PSA developments and applications in WGRISK member countries and some non-member countries through IAEA and shall particularly focus on lessons learned from post-Fukushima investigations and effects on the PSA.

Further ideas for future activities are an information exchange on probabilistic risk analyses for research reactors, the treatment of digital I&C in risk analyses, risk assessment for the spent fuel pool and PSA for harsh weather conditions.

It has to be emphasized that the reports by WGRISK are generally available to the public (including non-members of NEA) and can be found on the OECD/NEA website (e.g., http://www.oecd-nea.org/nsd/docs/indexcsni.html).

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