Highlights of the Technical Meeting on the Verification and Validation of Severe Accident Management Guidelines

Lovell Gilbert

Vienna International Centre, Austria

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Meeting highlights

Opening and Plenary Session:

1. PS-1: Findings in Accident Management Area in Nuclear Power Plant during OSART Missions: Mr. Fuming Jiang (IAEA)
2. PS-2: Contributions of the OECD/NEA Working Group on the Analysis and Management of Accidents (WGAMA) to the Severe Accident Field: Mr. Nils Sandberg (OECD/NEA)
3. PS-3: Severe Accident Management Guideline Uncertainty Investigation: Mr. Jeff Gabor (Jensen Hughes, U.S.A)/Mr. Randy Gauntt (Sandia NL, U.S.A)
**OSART Finding:**

- In some plants, the scope of the Severe Accident Management guidance does not systematically address accidents involving multiple units.
- In a few plants, the SAM strategies and arrangements are not complete or robust enough to ensure capability to take effective countermeasures.
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- In some plants, the verification and validation process for the Accident Management procedures and guidelines as well as changes to them is not comprehensively described in dedicated procedure or not applied effectively.
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Meeting highlights

• Purpose of proposed WANO SAM PO&Cs:
  – Intended to help in assessing station/utility performance during peer reviews.
  – Generalized standards of excellence reflecting best industry performance for nuclear power plants.
  – A description of a perfect, excellently performing nuclear power station, something for the member stations to strive for.
  – SAM PO&Cs can also be used by the member stations/utilities for self-assessment.
Meeting highlights

- If the SAMG approach utilizes the existing plant safety systems and other systems that have not been designed for severe accidents, survivability of the used equipment (including instrumentation) has to be demonstrated under the severe accident environment (e.g. pressure, temperature, radiation) during the time period for which the equipment is needed.
- Habitability assessment to ensure accessibility to key plant areas in severe accident conditions.
- How is the availability of SSCs used to manage the accident ensured during the life of the plant? (periodic test, inspections, operating limiting conditions)
- Strategies to manage extended station blackout (Loss of off-site power, and all on-site electrical power and DG) should be included in SAMG.
Technical Session 1: Overview of International Requirements, national regulatory and industry requirements and issues on the V&V of SAMGs

Chairperson: George Vayssier
Meeting highlights Technical Session 1

Technical Session 1 had five papers from India (Mr. Lakshmanan), Korea (Mr. Chung, Mr. Kim), Mexico (Mr. Mugica), and Belarus (Mr. Tretiakevich), treating the subjects of

• Application of safety analysis of for V&V of SAMG (Mr. Lakshmanan)
• Regulation of SAMG in Korea (Mr. Chung)
• Independent Evaluation by Reg. Body of SAMG for Laguna Verde (Mr. Mugica)
• Developing capacity for V&V of SAMG in Belarus (Mr. Tretiakevich)
• Revision of NS-G-2.15 and its implementation for V&V of AM guidelines (Mr. Kim)
Safety analysis for V&V of SAMG in India

Illustrated with a matrix for DBA and DEC on the horizontal axis, and the safety objectives-measures-procedures-analysis-equipment on the vertical axis

- Methodology follows NS-G-2.15
- Uses PSA 1+2 to find scenarios
- Looking for time window, survivability of equipment
- Highlight of operator actions, plant mods, add-ons, restoration of equipment, portable equipment
- Verification by plant analysis for 3 scenarios (by Reg. Body), bijv. IVR, H2
- Validation via various methods, must include uncertainties, should be realistic (time constraints, hazard work conditions)
- Paper shows various analyses.
- Overview of types accident, uses SCDAP/RELAP, ASTEC, CFD
- AERB does it own assessment, V&V
## Approach to Accident Management Programme

<table>
<thead>
<tr>
<th>Safety objective</th>
<th>Design basis accidents (DBA)</th>
<th>Design extension conditions (DEC)</th>
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<tbody>
<tr>
<td></td>
<td>Level-3 DID</td>
<td>Level-4 DID</td>
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<tr>
<td></td>
<td>Prevent significant fuel degradation and keep releases within acceptable limits</td>
<td>Terminate fuel damage, maintain the integrity of the containment for as long as possible. Minimize on-site and off-site releases and their adverse effects</td>
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<tr>
<th>Accident management strategy</th>
<th>Preventive</th>
<th>Mitigative</th>
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<tbody>
<tr>
<td>Measures</td>
<td></td>
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<tr>
<td>Credited plant equipment</td>
<td>Safety systems</td>
<td>Additional safety systems, complementary safety features</td>
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<tr>
<td>means</td>
<td>operator actions, plant modifications, additional provisions, recovery of failed equipment, use of non-permanent systems etc.</td>
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<tr>
<th>Procedures</th>
<th>Emergency Operating Procedures</th>
<th>Severe Accident Management Guidelines</th>
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<tr>
<td></td>
<td>Preventive Guidelines</td>
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<tr>
<th>Analysis</th>
<th>Deterministic safety</th>
<th>Plant specific analysis for DBA and DEC-A</th>
<th>Plant specific analysis for DEC-B</th>
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<tr>
<td>Probalistic safety</td>
<td>Level-1 PSA</td>
<td>Level-2 PSA</td>
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<th>Equipment and instrumentation</th>
<th>Equipment qualification</th>
<th>Equipment survivability assessment</th>
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SAMG Verification Analysis in AERB (Cont.)

LOCA+LECCS+LMODC with Calandria Hook-up (2/4)

Primary Pressure

Calandria Pressure
Regulation of SAMG in Korea

- Existing administrative orders re SAMG replaced by legal framework
- Special inspections, objectives
  - Design and operation measures against natural disasters
  - Mitigation capability against severe accident
  - Effectiveness of emergency response system

Additional orders:
- Improving the emergency response measures against man-made disasters as well as natural disasters;
- Operating an dedicated emergency response organization for severe accident management;
- Securing emergency response centre to protect emergency workers; and
- to secure equipment and systems for command and control
Regulation of SAMG in Korea-2

- Also stress tests were ordered

Legal elements /requirements (rulemaking):
- Contents and acceptance criteria for AMP
- Safety goals, accident management strategies, procedures and guidelines to control accidents, licensee’s staffing, education and training, etc.
- Design features and mitigation strategy to prevent and mitigate severe accidents resulting from multiple failures of safety systems as well as from extreme natural or man-made hazards
- Requirements on assessment of environmental impact from severe accidents
Evaluation of Lagune Verde SAMG

New elements added after Fukushima:
- Inspection Plan Revision and Updating
- Severe Accident Program Implementation
- Training as part of Severe Accident Program

Regulatory req´ments, refer to NRC EA-docs.
- BWROG approach
- Venting to the RB – to be modified
- SAMG V&V: options for Reg.Body involvement under analysis
- SAMG not enclosed in normal regulatory process
- Risk found for H2 combustion in vent pipe
  - ref. made to the various European plants with cont. vent lines.
Various analyses for LV

A number of analyses done:
• SBO with injection and SBO with no injection
• Small Break LOCA, Medium Break LOCA and Large Break LOCA (no injection)
• Reflooding
• Containment Failure Analysis
• Venting Strategies (cont. failure at 9 bar, venting at 4 bar)
  – Filtering cont. or not?
• Hydrogen Generation and Stratification Analysis
• Analysis with GASFLOW code of containment
• Reg. Body did not check SAMG development process at LV
• SAMG under development, now ß-phase
Developing capacity for V&V of SAMG in Belarus

- AES 2006 under construction in North-Belarus
- Many passive safety features, core catcher
- Symptom oriented approach selected for SAMG
- Tasks needed:
  - Creation of a legal basis
  - Developing competence
  - Existence of necessary materials and tools
- Use of Russian reg. documents (unless own documents)
- Ref. to Technica code and Russian RB 102.15
- Use internal and external sources (IAEA, EU ´permanent mission´) for building competence
  - Comp. codes ASTEC, Risk Spectrum
  - Full PSA 1 and 2 required
- SAMG required by March 2017
Revision of NS-G-2.15 and its implementation for V&V of AM guidelines

1. Revision of NS-G-2.15: SAMP for NPPs, due to lessons learned from F-accident; original version 2009
2. Verification and validation of severe accident management guidelines (SAMGs)
3. Source: IAEA action plan, consistency with new IAEA Requirements (SSR 2/1, 2/2), GSR Part 4, Part 7)
4. Many consultancy meetings, with many and varying countries (10 countries +ENISS)
5. Publication 2017-2018
6. Also under revision SRS 32 (Implementation of AMP)
   Major source doc for SAMG
Release of large amount of radioactive materials to environment

Gap Analysis of Lessons Learned from Fukushima Daiichi Accident

<Accident Progression>

Earthquake

- Reactor shutdown

Loss of off-site power

- Emergency DGs / core cooling systems started

Tsunami

- Multiple failures & common cause failures
  - Loss of emergency DGs & DC power

- Loss of core cooling function

Core damage

- Containment failure
  - Leak to reactor building

- Hydrogen explosion in reactor building

- Release of large amount of radioactive materials to environment

<Countermeasures>

- Enhancement of robustness against earthquake and tsunami

- Prevention of core damage
  - Enhancement of emergency power supply and core cooling

- Prevention of containment failure

- Suppression of release and dispersion of radioactive materials

※DG: Diesel Generator

Design basis height: 5.7m
Inundation height: 15.5m

Prevention of prolonged loss of off-site power

Enhancement of plant monitoring and control functions

Loss of communication & instrumentation functions
Examples of add-ons NS-G-2.15

- Storing flex components: potable/mobile pump, DG,
- Equipment qualification
- Transfer of responsibility
- Reliable communication network
- Decision making line and qualification of decision maker
- Multi-unit sites: sharing TSC and assign an overall emergency director, sharing equipment
- Failure of commend control due to a loss of MCR by large land damage.
Technical Session 2: Strategy, Tools and Methodology for V/V of SAMGs

Chairperson: Man Kim
Meeting highlights

Technical Session 2: Strategy, Tools and Methodology for V/V of SAMGs
•V/V strategy and evaluation by Industry’s V/V (3), RB’s V/V Evaluation (2), Tools (1), Methodology (1)

1TS2-1: OECD/NEA Project - Informing SAMGs and Actions through Analytical Simulations Mr Quanmin Lei (CNSC, Canada)
2TS2-2: Implementation of SAMG in PAKS NPP. Validation with SA Simulator. Ms Eva Toth (MVM Hungary)
3TS2-3: Verification and validation of accident management guidelines in Indian PHWR Mr Ritesh Raj (NPCI, India)
4TS2-4: Development of the Methodologies for Evaluating Accident Management Program Mr Joong Taek Lim (KINS, Korea)
5TS2-5: CNSC evaluation of station-specific SAMG Mr A Quanmin Lei (CNSC, Canada)
6TS2-6: Status of Verification and Validation of SAMGs in Sweden Mr Henrik Glaenneskog (Vattenfall AB, Sweden)
7TS2-7: Emergency procedures in KNPP-SAMG type. Development, verification and validation. Mr Tsvetan Topalov (Kozloduy NPP, Bulgaria)
Meeting highlights

Common Key Points:

• Symptom based SAMG requires more knowledge and training
  – in order to diagnose plant conditions and identify options for implementing
    viable countermeasures aimed to mitigating severe accidents.

• In the assessment of SAM effectiveness, analytical simulation alone is not
  sufficient to evaluate comprehensive assessment of SAM effectiveness.
  – Therefore, an integral evaluation id needed to takes into account all inputs
    such as from the review of SAMG documentation, personnel training
    results, and validation activities such as tabletop exercises, plant
    walkthroughs and drills, etc.
Common Key Points:

- Treatment of simulation uncertainty still remains a serious challenge for assessing SAM actions
  - SAMG actions are verified with analytical simulation using the best-estimate approach
  - Engineering judgement remains a part of interpretation of the simulation results and the overall evaluation of the SAMG actions.
  - Hence, the associated uncertainties should be recognized and, if necessary, quantified and then taken into account in the assessment.
- The time required to implement an action reflects human and organizational performance of a SAM staff (crew) during SAMG execution.
  - The time delay should be estimated based on tabletop exercises, plant walkthroughs, and plant drills.
Meeting highlights

Specific Key Points:

🌟 The CNSC’s evaluation of plant-specific SAMG effectiveness by using tabletop exercises and plant drills is recommended to compare with independent evaluation by third party to confirm its adequacy.
  - It is also recognized the need of evaluation guidelines and index, particularly, for non-technical aspect such as leadership

🌟 Following observations were made during validation efforts of hydrogen management in the SAMGs in Sweden.
  - If TSC staff is not familiar with SAMG, training SAMG for TSC staff is needed and is preferable with operator because of interaction with operators in MCR.
  - It is needed to clear the responsibilities and roles for TSC staff.
Meeting highlights

Good Practices to share with MSs:

✦ A full-scope simulator for severe accident conditions is beneficial tool for V/V of SAMG.
  – IAEA will organize the full-scope simulator owners’ group to support MSs’ SAMGs V/V if necessary.

✦ An approach of CNSC’s evaluation of plant-specific SAMG effectiveness would be beneficial information for independent evaluation of MS’s RB.

✦ To support SAMG V/V, simulation tools such as MAAP, MELCOR, ASTEC, and other tools are also useful for verification of SAMG modification.

✦ OECD/NEA Project document on “Informing SAMGs and Actions through Analytical Simulations” will be useful information for V/V of SAMG effectiveness,
Technical Session 3: Specific examples of recent experiences and issues related to SAMG V/V as lessons learnt from Fukushima Daiichi accident

Chairperson: Roy Harter
Meeting highlights

Technical Session 3: Specific examples of recent experiences and issues related to SAMG V/V as lessons learnt from Fukushima Daiichi accident
1TS3-1: Validation of SAMG at PAKS NPP, Mr Barnabas Bognar (MVM Hungary)
2TS3-2: Verification and Validation of CANDU Owners Group SAMGs, Mr Lovell Gilbert (Bruce Power, Canada)
3TS3-3: Experience with RAMP and other SAMG Review Mission, Mr George Vassier (NSC, Netherland)
4TS3-4: Verification and validation of SAMGs at Khmelnitsky NPP, Mr Valerii Pashynskyi (Khmelnitsky NPP, Ukraine)
5TS3-5: V&V of SAMG at Dukovany NPP, Mr Miroslav Trnka (Dukovany NPP, Czech)
6TS3-6: Development of SAMG Verification and Validation for Kashiwazaki-Kariwa Nuclear Power Plants, Mr Toshinobu Kita (TEPCO, Japan)
7TS3-7: Development and use of SAMGs in the Krsko NPP, Mr Tomaz Nemec (SNSA, Slovenia)
8TS3-8: Highlights from the Technical Meeting on In-Vessel Melt Retention and Ex-Vessel Corium Cooling, Mr Katsumi Yamada (IAEA)
Meeting highlights

- Verification and Validation (V&V) should be governed by a formal program document which describes roles and responsibilities, requirements, and the process for performing V&V activities. This is needed to ensure a rigorous, comprehensive, and consistent review of SAMG prior to implementation at an NPP. V&V should ensure that:
  - SAMG is **technically accurate** and has a sound bases (Verification).
  - SAMG is **written correctly** in accordance with writer’s guides that incorporate human factor principles to ensure ease of use (Verification).
  - SAMG is **operationally correct and usable** by operators and emergency response personnel under expected conditions of use.

- Validation should not be limited to assessing the effectiveness of SAMG, but also consider the leadership and decision making skills of the decision maker, evaluation skills of analysts, and teamwork and communications between all groups (the main control room, TSC, and other support groups).

- V&V processes should be in place to check the output of software codes and simulators that are used to support the development and training of SAMG.
Meeting highlights

- Rigorous V&V should be applied to the utilization of portable equipment in both the preventive and mitigative regimes.
- The V&V team should maintain some independence from the developers of to ensure there is not any pre-conceived bias that could influence V&V activities.
- V&V programs should include provisions to evaluate the ability to meet Time Critical Operator Actions (to support design analysis) and Time Sensitive Actions (to support regulatory requirements and station commitments).
- A technical bases should be prepared by vendors and/or utilities and utilized during verification to assess the technical adequacy of plant-specific SAMG.
- The psychological impacts on the ERO associated with severe accident conditions should be recognized and result in human factor improvements to both SAMG and computational aides to improve their use during high stress conditions. This challenge should be evaluated during validation.
- Validation should include a comprehensive review of both the resources needed and the timing of actions to implement SAMG strategies that entail the use of portable equipment in the field.
Lessons learned from IAEA OSART and RAMP missions, and available regulatory and industry reports should be utilized as Operating Experience (OE) in the development of V&V programs and evaluations. Industry reports which may be of benefit include:

- **US NRC NUREG-1358 Supplement 1** - Lessons Learned From The Special Inspection Program For Emergency Operating Procedures, provides a good historical perspective of shortcomings in V&V activities for EOPs which can by extension be applicable to SAMG

- **NEI 12-06 Rev 2** - Diverse and Flexible Coping Strategies FLEX Implementation, provides detailed recommendations on V&V strategies for the use portable equipment used in AMG.

- **NEI-14-06 Rev 1** - Organizational Approach to BDBE Planning, provides an approach to validate the impact of AMG and FLEX on ERO resources and NPP organizations

- **NEI-14-01 Rev 1** - Emergency Response Procedures and Guidelines for Beyond Design Basis Events and Severe Accidents, establishes requirements for SAMG V&V
Meeting highlights

**Good practices shared by member countries:**

- A full-scope simulator which models severe accident conditions can enhance the validation of SAMG and subsequent training of operators and ERO personnel. (Krsko, Dukovany, Kashiwazaki-Kariwa)

- A structured approach to SAMG development should be developed which ensures a sound technical bases, describes the derivation of SAMG, incorporates insights from PSA and other analysis, ensures input from operators, and includes formal V&V programs is a good practice. (TEPCO, Japan)

- External peer reviews of SAMG every two years to independently assess SAMG programs and implementing guidance. (Khmelnitsky, Ukraine)

- Comprehensive drills which test ERO implementation of portable equipment for BDB events over extended hours and in harsh conditions. (Bruce Power, Canada)

- Comprehensive analysis using MAAP, MELCOR, ASTEC, and other tools to support SAMG development, testing, and training. (Krsko, Dukovany, Kashiwazaki-Kariwa, Paks)
Thank you for your attention!