Nuclear Installation Safety: Priorities related to Small and Medium or Modular Reactors (SMRs)

Cornelia Spitzer
Head, Safety Assessment Section
Division of Nuclear Installation Safety
Department of Nuclear Safety and Security

2nd Technical Working Group on Small, Medium Sized or Modular Nuclear Reactors Meeting, Vienna, 9 July 2019
Outline

• IAEA Safety Standards
• Small and Medium or Modular Reactors (SMRs)
• New Design Safety Principles: Priorities
• Technical Safety Review (TSR) Services
• Conclusion
Safety Standards Hierarchy

Global Reference Point for a High Level of Nuclear Safety
Design Safety

Safety Fundamentals
- Safety objectives and safety principles
- Functional conditions required for safety
- Guidance on how to fulfil the requirements
Safety Assessment

Safety Fundamentals

Safety objectives and safety principles

Functional conditions required for safety

Guidance on how to fulfil the requirements

Safety Requirements

Safety Guides

IAEA Safety Standards
for protecting people and the environment

Deterministic Safety Analysis for Nuclear Power Plants
Specific Safety Guide No. SSG-2

IAEA Safety Standards
for protecting people and the environment

Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants
Specific Safety Guide No. SSG-3

IAEA Safety Standards
for protecting people and the environment

Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants
Specific Safety Guide No. SSG-4

IAEA SAFETY
STANDARDS
SERIES

Format and Content of the Safety Analysis Report for Nuclear Power Plants
SAFETY GUIDE
No. GS-G-1.1
Applicability

- **New Nuclear Power Plants**
  - Primarily to NPPs with water cooled reactors (land based stationary)
- **Nuclear Power Plants in operation**
  - It might not be practicable to entirely apply
  - Expected: comparison made against current standards, for example as part of the periodic safety review
- **Other reactor types**
  - With judgement to determine how the requirements have to be considered in developing the design
SMRs – Background

• About 50 different designs for SMRs, transportable and floating reactors in development

• Number of Member States interested in SMRs has increased over the past few years

• Convention on Nuclear Safety applies to any civil land-based NPP, including SMRs

• Transport of radioactive material by sea is governed by the *International Convention for the Safety of Life at Sea* (SOLAS) and the *International Maritime Organization* (IMO)
SMRs – Claims

• Innovations
  – Integral design / reduced number of DB initiators
  – Largely inherently safe
  – Passive safety systems / natural circulation
  – Limited / no operator action in response to accident scenarios (neither immediate nor delayed actions)

• Size
  – Decreased radioactive inventory & site footprint
  – Multi-module scalability – fit to capacity needs
  – Modular units – easy to deploy to remote sites
  – Decreased on-site construction time
SMRs – Challenges

• First-of-Kind for large number of different designs

• Unproven technology
  – Comprehensive analyses, simulations, and testing needed to close knowledge gaps
    • New design philosophy
    • New materials
    • New safety systems strategies

• Lack of operational experience

• Regulatory processes
  – Rules & Regulation, Safety Standards need to be adapted, as appropriate
AGENCY CONSIDERS

• Development of new safety requirements for a specific SMR technology
  NOT APPROPRIATE AT THIS STAGE

• Particularly, given the limited experience available and the variety of proposed designs
  HOWEVER

• Proposal and development of new reports
Emerging Topics

• To provide assistance to Member States in areas such as SMRs, TNPPs
  – Conduct of projects to compile available safety approaches and current understanding in the context of IAEA Safety Standards
  – Proposal and development of IAEA TECDOCs and Safety Reports to reflect converging understanding among stakeholders
  – Proposal and development of IAEA Safety Standards when matured practices in Member States available
IAEA Study on Applicability

- Review of current practices on applicability of IAEA Design Safety Requirements, SSR-2/1 (Rev.1), to SMR technologies

- 19 organizations from 10 Member States
  - Areva, BATAN, BWXT, CGNPC, CNEA, CNNC, Holtec, INET, IRSN, JAEA, KAERI, NPIC, NuScale, STL, Terrestrial Energy, USNC, Rolls-Royce, Westinghouse, X-Energy

- SMR Regulators’ Forum representatives
Study Performance

• Compiled participants view on the applicability of each IAEA Design Safety Requirement to their SMR technology

• Based on detailed templates filled: common understanding developed for two groups
  – Light Water Reactors
  – High Temperature Gas-Cooled Reactors

• Outcome: Project Report
Criteria

• Evaluation of all 82 Design Safety Requirements and their paragraphs
  – Applicable as is
  – Applicable with interpretation
    • No modification required, but
    • Rationale for the application of the requirement is different than that of the standard light water reactor
  – Applicable with modification
    • Edit/change requirement and/or paragraphs required
  – Applicable with new paragraph
  – Requirement/paragraph not applicable: further consideration needed
Major Results (1/2)

Suggested Considerations

![Bar chart showing LWR and HTGR with numbers 8 and 74 for LWR, and 26 and 56 for HTGR. The chart indicates that HTGR is more applicable as is.]
Major Results (2/2)

Suggested Considerations

- LWR
  - Applicable with interpretation
  - Applicable with modification
  - Applicable with new paragraph

- HTGR
  - Requirement or paragraph not applicable; further consideration needed
Technical Documents

IAEA TECDOC 1366
published in 2003

Considerations in the development of safety requirements for innovative reactors: Application to modular high temperature gas cooled reactors

IAEA TECDOC 1570
published in 2007

Proposed Approach

DESIGN AND LICENSING RULES FOR CURRENT WATER REACTORS

Requirements (General)

Requirements (Specific)

Recommendations for the Design

MAIN PILLARS
- SAFETY OBJECTIVES
- FUNDAMENTAL SAFETY FUNCTIONS
- DEFENCE IN DEPTH

NEW APPROACH
- MORE “RISK” INFORMED
- LESS PRESCRIPTIVE

CRITICAL REVIEW

1) Understanding:
- the rationale behind each requirement
- the contribution of each requirement to defence in depth
- whether the requirement is technology-neutral or technology-dependent

2) Application of an Objective-ProvisionsTree

RECOMMENDATIONS FOR THE DESIGN

Recommendations for the Design

Requirements (General)

Requirements (Specific)

MAIN PILLARS
- QUANTITATIVE SAFETY GOAL
- FUNDAMENTAL SAFETY FUNCTIONS
- DEFENCE IN DEPTH (Enhanced)
Regulatory Safety Requirements

• Utilization of insights obtained from the study
  – Light Water Reactors
  – High Temperature Gas-cooled Reactors

• Application of Logical Framework to illustrate the Development of Regulatory Safety Requirements for SMRs

• Assistance to Member States for their own application, if so wished
IAEA TECDOC: Content

• Review and update of safety approach taking into account the revised IAEA Safety Standards, as needed
• IAEA Design Safety Requirements, SSR-2/1 (Rev. 1)
  – Selection of representative safety requirements
• Application of proposed approach and illustrative development of safety requirements for two SMR technologies
  – Light Water Reactors
  – High Temperature Gas-cooled Reactors
Graded Approach

• Development of IAEA TECDOC

Application of Graded Approach in Regulating Nuclear Power Plants, Research Reactors and Fuel Cycle Facilities

• Covering all regulatory functions and types of nuclear installations

• Documenting Member States’ practices & possible generic methodologies
Safety Report

- Broaden scope to comprehensively address safety assessment of SMRs (near term deployment)
  - Defence in depth
  - Safety margins
  - Safety barriers
  - Deterministic Safety Analysis
  - Probabilistic Safety Assessment
  - Safety Analysis Report
    - Examples in Annexes
Technical Meeting on SMRs

- TM on Safety Assessment and Analysis of SMRs
  - Discuss views and experience from Member States regarding Safety Assessments for SMRs
    - Safety Assessments performed
    - Regulatory Requirements
    - Application of IAEA Safety Standards to SMRs
    - SMR Regulators’ Forum insights and discussions
  - Vienna, Austria
  - 4 – 8 November 2019
CRP on EPZ for SMR Deployment

• CRP I3 1029: Development of Approaches, Methodologies and Criteria for Determining the Technical Basis for Emergency Planning Zone for Small Modular Reactor Deployment

• Overall Expected Outcome
  – Definition of consistent approaches, methodologies, criteria to determine need for off-site EPR, including EPZ/D size, for SMR deployment
  – Includes identification of technology specific factors for different SMRs that may influence
    • source term and timing of release
    • possible sequences to be considered for emergency classification system
Countries Participating

• Under Research Agreement:
  – China
  – United Kingdom
  – Japan
  – Finland
  – Netherlands (representing EC through JRC-Petten)
  – Pakistan
  – Saudi Arabia (with Republic of Korea)
  – Canada
  – USA

• Under Research Contract:
  – Indonesia
  – Tunisia
  – Israel
  – China
  – Argentina
Current Status

• RCM-1, Vienna, May 2018; main outcome
  – Presentation of objectives and scope of the planned research to be conducted by each participant entity
  – Definition of Table of Contents of the CRP Report

• RCM-2, Beijing, China, 27-31 May 2019
  – Discussion and exchange of progress made by participants and way forward

• Project to be completed in 2020

• RCM-3 dates to be determined
SMR Regulators’ Forum

Members

• Canada
• China
• Finland
• France
• Republic of Korea
• Russian Federation
• Kingdom of Saudi Arabia
• United Kingdom
• United States of America

Observers

• European Union
• OECD / NEA
New Design Safety Principles

### Earlier Concept

<table>
<thead>
<tr>
<th>Operational States</th>
<th>Accident Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>DBAs (safety systems)</td>
</tr>
<tr>
<td>AOO</td>
<td>BDBA</td>
</tr>
<tr>
<td></td>
<td>Severe Accidents (core melting)</td>
</tr>
</tbody>
</table>

### SSR-2/1, 2012

<table>
<thead>
<tr>
<th>Operational States</th>
<th>Accident Conditions</th>
<th>Conditions practically eliminated</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>DBAs (safety systems)</td>
<td>Safety features for accident with core melting</td>
</tr>
<tr>
<td>AOO</td>
<td></td>
<td>Safety features for sequences without significant fuel degradation</td>
</tr>
</tbody>
</table>

Plant Design Envelope
Priorities (1/3)

• Finalise & publish revision of 13 safety assessment and design safety guides
• Develop new safety guide: Assessment of the Application of General Requirements for Design of Nuclear Power Plants (DS508)
• Safety reports
  – Implementation of Accident Management Programmes in Nuclear Power Plants
  – Human Reliability Analysis for Nuclear Installations
  – Safety Aspects of Using Smart Digital Devices in Nuclear Safety Systems
Priorities (2/3)

• Technical documents
  – In-Vessel Melt Retention and Ex-Vessel Corium Cooling – Summary of a Technical Meeting
  – Current Approaches in Member States to the Analysis of Design Extension Conditions for New Nuclear Power Plants
  – Experience in applying the new IAEA Design Safety Principles to New Nuclear Power Plants
  – Experiences on implementing safety improvements at existing nuclear power plants: approaches and strategies aiming at minimising radioactive releases in the event of a nuclear accident
  – Level 1 Probabilistic Safety Assessment for Nuclear Power Plants with Candu-Type Reactors
Priorities (3/3)

• Technical documents
  – Development and Application of a Safety Goals Framework for Nuclear Installations (published)
  – Considerations on Performing Integrated Risk Informed Decision Making

• Conduct projects and develop reports
  – Use of Passive Safety Features in Nuclear Power Plant Designs and their Safety Assessment
  – Development of Methodology for Aggregation of Various Risk Contributors for Nuclear Facilities
  – MUPSA project: Phase II – MUPSA Case Study
  – MUPSA project: Phase III – Improvement of the MUPSA methodology based on the feedback from the Case Study
IAEA Safety Guides

- Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants (DS481)
- Design of Reactor Containment Systems for Nuclear Power Plants (DS482)
- Protection against Internal Hazards in the Design of Nuclear Power Plants (DS494)
- Design of Fuel Handling and Storage Systems for Nuclear Power Plants (DS487)
- Design of the Reactor Core for Nuclear Power Plants (DS488)
- Design of Auxiliary and Supporting Systems for Nuclear Power Plants (DS440)
- Human Factors Engineering in Nuclear Power Plants (DS492)
- Deterministic Safety Analysis for Nuclear Power Plants (DS491)
- Format and Content of the Safety Analysis Report for Nuclear Power Plants (DS449)
- Accident Management Programmes for Nuclear Power Plants (published)
- Assessment of the Application of General Requirements for Design of Nuclear Power Plants (DS508)
- Qualification of Items Important to Safety in Nuclear Installations (DS514)
- Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants (DS523)
- Radiation Protection Aspects of Design for Nuclear Power Plants (DS524)
Major Meetings (1/3)

• Technical Meeting on Current Practices in the Transition from Emergency Operating Procedures to Severe Accident Management Guidelines, 27-30 August 2019, Vienna, Austria

• Technical Meeting on Multi-Unit Probabilistic Safety Assessment, 7-10 October 2019, Vienna, Austria

Major Meetings (2/3)

- Workshop on Deterministic Safety Analysis and the Format and Content of the Safety Analysis Report, 2-6 September 2019, Beijing, China
- Workshop on the Application of the Latest IAEA Recommendations for the Design of the Reactor Coolant System and the Reactor Containment Structure Systems for NPPs, 9-13 September, Vienna, Austria
Major Meetings (3/3)

• Workshop on Current Practises in the Preparation, Modification and Review of Safety Analysis Reports for Nuclear Power Plants, 23-27 September 2019, Shanghai, China

• Workshop on the Applications of the New IAEA Safety Requirements for Nuclear Power Plant Design, 30 September - 4 October 2019, Vienna, Austria

• Regional Workshop on Level 3 Probabilistic Safety Assessment, 14-17 October 2019, Budapest, Hungary
Safety Review Services: New Entrants

**INFRASTRUCTURE FOR NUCLEAR POWER PLANT**

- Phase 1 (1-3 years)
  - Ready to make a knowledgeable decision
  - Site survey
- Phase 2 (3-7 years)
  - Site selection & assessment
  - Essential Legal and regulatory framework
  - Global Nuclear Safety Regime
- Phase 3 (7-10 years)
  - Site Permit
  - Construction license
  - Submission of application for Construction license (PSAR)
  - Submission of application for operating license (PSAR)
  - Core fuel load
  - Operating license

**GENERIC PEER-REVIEW SERVICES**

- IRRS Full scope + Tailored Module
- IRRS Follow-up + Full Scope NPP

**TECHNICAL PEER-REVIEW SERVICES**

- **SEED:** Site and design safety
  - Site and Design Regulations
  - Site Selection Process
- **SEED:** Site Evaluation
  - Environmental Impact Assessment
- **SEED:** External Hazards
- **TSR:** Safety Requirements
  - Generic Reactor Safety
  - Site Monitoring
- **TSR:** Design Safety
  - Probabilistic Safety Assessment

**SPECIFIC PEER REVIEW SERVICES**

- **ISCA** Institutional strength
- **ISCA** Regulatory Body
- **PROSPER** Operator (construction)
- **ISCA** Operator
- **SALTO** Operator (Ageing)

Review of Safety Infrastructure for NPP in line with SSG-16

- IRRS: Regulatory Framework
- Pre-OSART: Operational Safety
- SEED: Site and design safety
- TSR: Technical Safety Review
- ISCA: Culture for Safety
- PROSPER: Operational Experience
- SALTO: Ageing Management

---

39
Technical Safety Review (TSR)

The TSR Peer Reviews incorporates IAEA safety assessment and design safety technical review services to address the needs of Member States at most stages of development and implementation of the nuclear power programme.
Review Services Conducted

Subject areas
- Design Safety (DS)
- Generic Reactor Safety (GRS)
- Safety Requirements (SR)
- Probabilistic Safety Assessment (PSA)
- Accident Management (AM)
- Periodic Safety Review (PSR)

Audience: Regulatory Bodies, TSOs, Owners/Operators
Duration: 6 – 9 months

Technical Team: Lead by IAEA staff
# experts: dependent on scope

North America 1
Europe 79
Asia and the Pacific 29
Africa 1
Latin America and the Caribbean 2

112 TSR Services*

* total number of services to date
## TSR Ongoing and Inquired

<table>
<thead>
<tr>
<th>Number</th>
<th>Subject Area</th>
<th>Member State</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Design Safety (DS)</td>
<td>Hungary</td>
<td>Formal request received</td>
</tr>
<tr>
<td>2</td>
<td>Design Safety (DS)</td>
<td>Turkey</td>
<td>Formal request received</td>
</tr>
<tr>
<td>3</td>
<td>Probabilistic Safety Assessment (PSA)</td>
<td>Turkey</td>
<td>Formal request received</td>
</tr>
<tr>
<td>4</td>
<td>Design Safety (DS)</td>
<td>Bangladesh</td>
<td>Completed Q2 2018</td>
</tr>
<tr>
<td>5</td>
<td>Periodic Safety Review (PSR)</td>
<td>Czech Republic</td>
<td>Completed Q1 2018</td>
</tr>
<tr>
<td>6</td>
<td>Safety Requirements (SR)</td>
<td>Nigeria</td>
<td>Ongoing: completion expected Q1 2020</td>
</tr>
<tr>
<td>7</td>
<td>Safety Requirements (SR)</td>
<td>Egypt</td>
<td>Completed Q3 2019</td>
</tr>
<tr>
<td>8</td>
<td>Generic Reactor Safety (GRS)</td>
<td>France/Japan</td>
<td>Interest expressed via email</td>
</tr>
<tr>
<td>9</td>
<td>Safety Requirements (SR)</td>
<td>Saudi Arabia</td>
<td>Completed Q1 2019</td>
</tr>
<tr>
<td>10</td>
<td>Generic Reactor Safety (GRS)</td>
<td>UK</td>
<td>Interest expressed via email</td>
</tr>
<tr>
<td>11</td>
<td>Probabilistic Safety Assessment (PSA)</td>
<td>Mexico</td>
<td>Interest expressed via email</td>
</tr>
</tbody>
</table>
Conclusion (1/2)

• Focused attention to encourage and provide assistance to Member States in the application of the IAEA safety standards
  – Complete revision of safety guides
  – Development of associated technical documents and safety reports
  – Continuation of CRP on Emergency Planning Zone for Small Modular Reactor Deployment
  – Provision of tailored workshops, lectures and training
  – Collaboration in activities related to technology development and deployment
Conclusion (2/2)

• Implementation of Technical Safety Review (TSR) services
• Particular actions ongoing and planned to support design safety considerations for new technologies
• Participation in IAEA activities very welcome to effectively feed the development and/or necessary launch of IAEA documents
Thank you for your kind attention!
C.Spitzer@iaea.org