
Javier Yllera
Division of Nuclear Installation Safety
Definitions

SMALL AND MEDIUM SIZE REACTORS (SMRs)

• Small-sized reactors: $< 300$ MW(e),
• Medium-sized reactors: $300 \rightarrow 700$ MW(e).

ADVANCED DESIGN

• Plants for which improvement over its predecessors and/or existing designs are expected. Advanced plant consist of evolutionary designs and designs requiring substantial development efforts. The latter can range from moderate modifications of existing designs to entirely new design concepts.

• EVOLUTIONARY DESIGN
  Advanced design that achieves improvements over existing designs through small and moderate modifications maintaining design “proveness” to minimize technological risks. Its development requires at the most engineering and confirmatory testing.

• INNOVATIVE DESIGN
  Advanced design which incorporates radical conceptual changes in design approach or system configuration in comparison with existing practice. Substantial R&D, feasibility tests, and a prototype or demonstration plant are probably required.

from IAEA-TECDOC-936 Terms for describing new, advanced nuclear power plants, 1997
Current Situation

**Current Situation**

**Evolutionary Reactors**
- Safety Standards

**Innovative Reactors**
- No Safety Standards
  - Safety Approach
  - Best Use of the Current Good Practice

Development of Safety Standards

IAEA
Some challenging questions

1. Is the current safety approach suitable to innovative reactors, including SMRs?

2. Is it possible to develop technology neutral safety approach and design safety requirements?

3. Is it possible to develop a technology-neutral safety driven design process?

4. How to integrate in the design process deterministic and probabilistic considerations?

5. How to assess the adequacy of implementation of defence in depth?
CURRENT RULES & REGULATIONS DEVELOPED MAINLY FOR LWRs

CURRENT APPROACH TO SAFETY & LICENSING
- Safety Objectives
- Fundamental Safety Functions
- Defence in Depth
- PSA considerations

RULES & REGULATIONS FOR INNOVATIVE REACTORS

TECHNOLOGY NEUTRAL APPROACH TO SAFETY & LICENSING
- Safety Goal (Quantitative)
- Fundamental Safety Functions
- Defence in Depth (generalized)
LIST OF CONTENTS

1. INTRODUCTION
2. MODEL TO DEVELOP SAFETY REQUIREMENTS FOR NEW NPPS
   - Current IAEA Safety Approach
   - Current IAEA Safety Standards
   - Proposed new safety approach
3. METHODOLOGY TO GENERATE TECHNOLOGY-NEUTRAL SAFETY REQUIREMENTS
   - Design Basis Conditions
   - The Objective-Provision tree method
   - Process to develop a safe design
   - Appendix I. Sample Proposal of Technology Neutral Safety Requirements
     - Elaboration of the requirements of NS-R-1
   - Appendix II. Postulated Initiating Events
   - Appendix III. Redundancy, Diversity and Independence
   - Appendix IV. Defence in Depth
   - Glossary
SAFETY OBJECTIVES
- General Nuclear Safety Objective
- Radiation Protection Objective
- Technical Safety Objective

SAFETY GOAL

FUNDAMENTAL SAFETY FUNCTIONS
- Confinement of radioactive material
- Control of reactivity
- Removal of the heat from the core

IMPLEMENTATION OF DEFENCE IN DEPTH
- Level 1 (Prevention)
- Level 2 (Control)
- Level 3 (Accidents Condit.)
- Level 4 (Severe Plant Cond)
- Level 5 (Off-site Mitigat.)

ProBABILISTIC SUCCESS CRITERIA

DETERMINISTIC SUCCESS CRITERIA

DEVELOPMENT OF SAFETY REQUIREMENTS

SAFETY REQUIREMENTS
LOGIC FLOW DIAGRAM OF DEFENCE IN DEPTH*

Challenges/Mechanisms Affecting the Performance of Safety Functions

Provisions for Level 1 of Defence in Depth

Objective: Prevention of abnormal operation and failure

LEVEL 1

Initiating Event

Provisions for Level 2 of Defence in Depth

Objective: Detection of failures and control of abnormal operation

LEVEL 2

Complex Operational Occurrences and ACs

Provisions for Level 3 of Defence in Depth

Objective: Control of Accidents Conditions (ACs) within the Design Basis

LEVEL 3

Severe Plant Conditions

Provisions for Level 4 of Defence in Depth

Objective: Control of Severe Plant Conditions within the Design Basis

LEVEL 4

Significant Radioactive Release

Provisions for Level 5 of Defence in Depth

Objective: Mitigation of radiological consequences of significant releases of radioactive material

LEVEL 5

* As defined in INSAG -12 and IAEA SSs
Approach to establish safety requirements for the design of innovative NPPs

**Design and Licensing Rules for Current Water Reactors**
- **Main Pillars (Current Approach)**
  - Safety Objectives
  - Fundamental Safety Functions
  - Defence in Depth (Deterministic)
  - PSA

**Design and Licensing Rules for a Given Innovative Reactor**
- **Main Pillars (New Approach)**
  - Quantitative Safety Goal
  - Fundamental Safety Functions
  - Defence in Depth (Generalized) which includes probabilistic considerations

**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 the Objective-Provisions Tree

**Requirements (General)**
- Safety Requirements (SSR 2/1)
- Safety Guides (SS NS-G-1…)

**Requirements (Specific)**
- Technology neutral
- Technology dependent
General safety goal and defence in depth

Initiating Events are caused by Failures of the Level 1 of D.I.D

Events managed by Lev 2 of D.I.D

Events managed by Lev 3 of D.I.D

Events managed by Lev 4 of D.I.D

AOO

UNACCEPTABLE CONSEQUENCES

AC

SPC

1 mSv/y

No need for off-site actions

Minimal emergency actions beyond defined distance

IAEA
Assessment of the Implementation of the Defence In Depth - Objective - Provisions Tree

Level of Defence

Level of Defence in depth (e.g. Level 1)

Safety Function

To be performed successfully (e.g. heat removal)

Objectives

To be achieved (e.g. prevention of deviation from Normal Operation)

Challenge

To cope with (e.g. disruption of heat transfer path)

Mechanism

To be prevented or controlled (e.g. loss of coolant)

Provision

To be implemented to prevent and/or control mechanisms (e.g. conservative design, seismic design)

Line of Protection (LOP): Set of provisions that jointly ensure the prevention or control of the mechanism
IMPACT OF THE IAEA-TECDOC-1570

• REPORT PREPARED BY THE RISK AND SAFETY WORKING GROUP (RSWG) OF GIF
  • The safety approach of the report reflects all the ideas developed during the work for the preparation of the TECDOC-1570
  • The report contains more details in the description of the safety approach
  • The report does not include safety requirements

• USE BY THE GIF SAFETY DESIGN CRITERIA (SDC) TASK FORCE FOR THE DEFINITION OF SDCs FOR SODIUM COOLED FAST REACTORS

• REVISION OF THE PREVIOUS IAEA SAFETY REQUIREMENTS FOR THE DESIGN (NS-R-1). NEW VERSION (SSR 2/1):
  • Better separation between Technology Neutral and Technology Specific Safety Requirements
  • Terminology and definitions (e.g. Severe accidents, Design basis)
IAEA Design & Safety Assessment Review Service (DSARS)

- Module for Generic Reactor Safety Review.

- Based upon Requirements for NPP Design (SSR 2/1) and Safety Assessment (GRS Part 4)
- Design Reviews Conducted upon request of MSs, including SMRS:
  - AP1000 – WESTINGHOUSE
  - EPR – AREVA
  - ACR 1000 – AECL
  - ESBWR – GE HITACHI
  - ATMEA 1 – AREVA – MHI
  - APR1400 – KHNP
  - APR1000 – KEPCO
  - AES 2006 – ROSENERGOATOM
  - ACPR 1000+ - CHINA
  - WWER TOI – in process
THANKS FOR YOUR ATTENTION