Harmonized EUR revision E requirements corresponding to currently available technical solutions

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Contents

- Project Overview
- Basic Safety Concept
- Changes due to Fukushima Lessons Learned
- Safety Classification
Objectives

A major objective of the EUR Utilities through the EUR document is to provide the basis for designing **safe and competitive** standard Nuclear Islands which can be licensed, built and operated in the majority of European countries with only minor variations, using a standard safety case and Standard Design studies.

The up-to date harmonized requirements participate to establish a standard presenting no harm to **environment** and **neighbouring population** under any foreseeable circumstance.
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Project overview
Revision E was launched in April 2014 on the basis of 11 position papers

- 29 chapters and ~1500 pages: about 5500 requirements
- 16 EUR utilities involved
- 98 European experts
- 33 months of work (April 2014 - December 2016)

Technical scope of Revision E

- Safety
- Fukushima lessons learned
- Safety Classification
- Radiological consequences
- Probabilistic Safety Analysis (PSA)
- Instrumentation & Control (I&C)
- Pipe Break
- Grid Connection
- Seismic approach
- Layout
- Structure of document EUR

EUR Utilities:
- CEZ
- EDF
- EDF Energy
- ENERGATOM
- FORTUM
- ENERGOATOM
- FORTUM
- GENenergija
- HORIZON
- IBERDROLA
- MVM PAKS II
- NRG
- ROSENERGOATOM
- TVO
- VGB PowerTech

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Timeline

WENRA Safety Reference Levels for existing reactors (2007)
WENRA Safety Reference Levels for existing reactors (2008)
WENRA Safety Reference Levels for existing reactors (Sept. 2014)
WENRA Safety Report for new reactors (March 2013)
IAEA Safety Reference Levels for existing reactors (2014)
IAEA SSR-2/1 Rev. 1
IAEA GSR Part 4 Rev. 1
IAEA GSR Part 4 Rev. 1
IAEA SSR-2 Rev. 1
IAEA SSG-2 Rev. 1 (DS491 Step 8a)
IAEA SSG-30
ongoing EUR Revision


Fukushima accident

EUR Rev. C
Apr 2001
EUR Rev. D
Oct 2012
EUR Rev. E

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Documents used

IAEA: SF-1, GSR Part 4 Rev.1, SSR-2/1 Rev.1, SSG-2 Rev.1 (DS491, Step 8a), SSG-3, SSG-4, SSG-30, TECDOC 1791, TECDOC 626


ENSTO-E, ENSREG,.....

Revision intentions

- Requirements to be generally and functionally phrased
- The requirements of IAEA and WENRA have to retain their original wording as widely as possible for traceability reasons
- The EUR terminology is preferred
- Where contradictions occurred among the requirement sources, the IAEA terminology was used
- Number of the requirements to be similar as in EUR Rev. D

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Main developments

New structure: EUR document more suited to « licensing » & « bidding » processes

New EUR Policies: Safety ; Economics ; Environmental protection
Operational performance ; Human factors

Safety: New chapter ; improved coherence with up-to-date international documents such as EURATOM Directives, WENRA Standards, IAEA guides, ..

Safety Classification: New approach in line with IAEA SSG-30

Radiological consequences: New safety objectives in line with WENRA

External hazards: New approach for external hazards based on two levels of magnitude (WENRA)

I&C: New chapter fully in line with IEC standards (61513, 60880, 62138, 61226)

PSA: Update of EUR chapter in line with IAEA SSG-3 and SSG-4

Grid Connection: EUR text in line with the new ENTSO-E Grid Code (June 2015)

Pipe Break: Update of EUR requirements dealing with Break Preclusion and LBB

Layout: Update of EUR requirements based on up-to-date international standards

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**Defence in depth approach in EUR Rev. E**

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**Level 3b consistent with WENRA**

<table>
<thead>
<tr>
<th>Levels of defence in depth</th>
<th>Objective</th>
<th>Essential means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Prevention of abnormal operation and failures</td>
<td>Conservative design and high quality in construction and operation</td>
</tr>
<tr>
<td>Level 2</td>
<td>Control of abnormal operation and detection of failures</td>
<td>Control, limiting and protection systems and other surveillance features</td>
</tr>
<tr>
<td>Level 3a</td>
<td>Control of accident within the design basis</td>
<td>Safety systems and accident procedures</td>
</tr>
<tr>
<td>Level 3b</td>
<td>Control of complex sequences &amp; prevention of core melt</td>
<td>Dedicated safety features and accident procedures</td>
</tr>
<tr>
<td>Level 4</td>
<td>Control of severe plant conditions &amp; releases</td>
<td>Dedicated safety features and accident management</td>
</tr>
<tr>
<td>Level 5</td>
<td>Mitigation of radiological consequences of significant releases of radioactive material</td>
<td>Off-site emergency response</td>
</tr>
</tbody>
</table>

**Engineering Design Rules (EDR 1 & 2)**
- Redundancy
- Diversification
- Independence
- Safety classification
- Analysis methods
- Safety assessment
- Boundary conditions

**Radiological Impacts:**
- Radiological Objectives O1, O2 and O3 consistent with WENRA
- Radiological targets for O2 & O3 defined in consistency with EUR CLI

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Practical elimination

Meaning
physical impossibility, or
extremely unlikely to arise with a high degree of confidence

Required

• Sequence leading to Large or Early Releases to be Practically Eliminated
• Cumulative frequency of sequences leading to Large or Early Releases shall be well below* the cumulative target for sequences slightly exceeding CLI values (10^-6 per reactor year).
  * at least one order of magnitude for internal events

Sequences to be practically eliminated

• Hydrogen detonation,
• Large steam explosion,
• Direct containment heating,
• Large reactivity insertion
• Rupture at high pressure of major pressure retaining components
• Fuel failure in a spent fuel store,
• Primary Containment over pressurization,
• Late containment failure due to base mat melt through,
• Severe Accidents (SA) challenging the Containment System
• SA in the shutdown state (containment open, SA mitigate measures disabled)
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Terminology and analysis methods

Terminology has undergone a major revision based on IAEA and WENRA used terms.

Plant states *(adopted from IAEA Table)*

- Operational states have been extended from Normal Operation to Anticipated Operational Occurrences
- Accident Conditions have been extended to DEC
- There is no “Beyond Design”! All Design Conditions are included in the Design!

Safety Analysis methodologies

- three graded methodology
- preferred: “best estimate computer codes with conservative and/or realistic input data” coupled with uncertainty analysis
- idle: conservative approaches both in input data and in the codes themselves could be applied

DEC A:
- Best estimate approach with adequate level of confidence
- Adequate margin with regard to Cliff Edge Effects

DEC B:
- Realistic Best estimate analysis
- Uncertainty and sensitivity analysis to demonstrate robustness

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Changes due to Fukushima Lessons Learned

- Reinforcement of the prevention of Large Releases through additional design measures and requirements
- Supplement to the mitigation approach of severe accident situations through additional emergency equipment and procedures

Main changes:
- Natural phenomena and site hazards to be considered (DBEH & RSEH)
- Plant Autonomy - Long term safety
- Ultimate Heat Sink - Primary and consideration of loss of UHS
- Emergency Power Supply - Diversity, redundancy, independence, autonomy
- Spent Fuel Safety - Practical elimination of fuel uncovery
- Severe Accidents Management
- Multiple Units issue - Shared systems, inter-connections
- Provisions for connecting points of non-permanent equipment
- Specific issues - fail-safe design concept, independence in I&C design
- Other considerations: specific sequences (UHS + SBO, ELAP) considered to define provisions (like Non Permanent Equipment and connection points)
- There is no “Beyond Design” concept

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Strengthened potential against external hazards

**DBEH: Design Basis External Hazard**
- plant is designed for
- mostly affect DBC1-4, maybe initiates Complex sequences (level 3b)
- conservative methodology
- radiological objective: O2

**RSEH: Rare and Severe External Hazard**
- for probabilistic evaluation that O3 objectives are met (applies at level 4)
- Complex sequences may be initiated (3b)
- realistic evaluation and best estimate rules
- Environmental condition resistance level 2

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### For Site Specific Design:

Severity levels on Return Period for Natural External Hazards:

- **DBEH** value $> 10^{-4}$/year
- **RSEH** value $<< 10^{-4}$/year

### For Standard EUR plant Design

Reference standard values both for DBEH and RSEH have been formulated by participating utilities (European balanced values representative of an European mean site, to permit an easy adaptation in each European country)

### Natural External Hazard

<table>
<thead>
<tr>
<th>Natural External Hazard</th>
<th>Design Basis External Hazard level</th>
<th>Rare and Severe External Hazard level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Extreme rainfall</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>External flooding</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Extremes of air temperatures &amp; humidity</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Extremes of heat sink temperatures (drought)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Extreme wind</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tornadoes and associated missiles</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lightning</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Snow</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Heat sink clogging by Biological phenomena (seaweeds, fish, marine growth)</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

**External Human made Hazard (non natural phenomenon) to be considered for Design Basis at Standard Design phase**

- Accidental aircraft crash, Yes
- External explosions, Yes
- Heat sink clogging by oil spill, Yes
Plant autonomy

Ultimate heat sink and electric power supply:

- Capability should be ensured for **7 days** without off-site support in all plant states (increased from 72 hours).
- Raw water reserves shall ensure for **30 days** autonomy in case the UHS is provided by water reservoirs.
- Autonomy objectives are also valid for **RSEH** (*Rare and Severe External Hazard*)

Non-Permanent Equipment (NPE):

- No on-site NPE shall be credited in the safety demonstration (irrespective whether it is light or heavy) during the **first 72 h** following the accident initiation.
- Use of light NPE after **24 h** in case of Complex Sequences or Severe Accident is allowed when safety classified.
- Off-site NPE can be credited after **7 days** only (increased from 72 h)*

* alternative solutions after 72 h (like heavy NPE, emergency response organization, regional or national Non Permanent Equipment* storage centers, etc) can be envisaged at site specific design if allowed according to the specific country regulation. The efficiency of such alternative solution is to be demonstrated.

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Spent fuel pool (SFP) cooling

• Practical elimination of accident sequence involving fuel melt
• SFP cooling function to be ensured in Rare and Severe External Hazards
• Structural integrity to be maintained for internal hazards, DBEH and RSEH
• 2 independent SFP water level monitoring instrumentation
• Loss of SFP cooling function due to SBO and/or LUHS considered in the rev E requirements (APS, provisions for the management of the boiling situations, till cooling function is reinstate)
• Robustness provisions for total loss of SFP cooling function
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Introduction of four factors for safety significance analysis.

Direct link between safety function categories and safety classes.

Design provisions are classified directly based on the severity of their failure independently of their function.

Harmonised with IAEA SSG-30.
(a) Cat.2 functions can be credited if it is demonstrated that the consequences of their failure are of “medium severity”; 
(b) Cat.3 functions can be credited if it is demonstrated that the consequences of their failure are of “medium severity”; 
(c) Cat.2 if the function is designed to provide a backup of a Cat.1 function; Cat.3 in other cases
Environmental condition resistance levels

Level 1
Shall be applied to all SSCs which are required:
- to remain functionally operable and/or structurally intact in DBC 2-4
- in case of DBEH conditions, to meet the Safety Objective for accident without core melt
- in case of Complex Sequence which is not initiated by RSEH (Rare and Severe External Hazard)

Level 2
Shall be applied to SSCs required:
- in case of Severe Accidents or event initiated by RSEH, to meet the safety objective for Accidents with Core melt
- for handling Complex Sequences initiated by RSEH

Level S
- SSCs which themselves are not required to remain operable or structurally intact, but whose failure could prevent SSC assigned to Level 1 and Level 2 from functioning as designed shall be assigned to Level S
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Thank you for your attention!