RISK-INFORMED DESIGN FOR CAP1400

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INTRODUCTION OF CAP1400

- Advanced Generation III Reactor
- Designed by SNERDI
- To be Constructed in Shandong, China
- Passive safety concept
- 72 hours without operator interaction
- A full scope, all-modes PSA
- Risk-informed design
## INTRODUCTION OF CAP1400

### Technical specifications of CAP1400

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameters</th>
</tr>
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<tbody>
<tr>
<td>Design lifetime</td>
<td>60 years</td>
</tr>
<tr>
<td>Reactor power</td>
<td>4040 MWt</td>
</tr>
<tr>
<td>Electrical power</td>
<td>~1500 MWe</td>
</tr>
<tr>
<td>Reactor operating pressure</td>
<td>15.5 MPa</td>
</tr>
<tr>
<td>Hot leg temperature</td>
<td>323.7 °C</td>
</tr>
<tr>
<td>Number of SGs</td>
<td>2</td>
</tr>
<tr>
<td>Number of reactor coolant pumps</td>
<td>4</td>
</tr>
<tr>
<td>Volume of containment</td>
<td>&gt;75000 m³</td>
</tr>
</tbody>
</table>
RISK-INFORMED DESIGN

Risk-informed method and design improvement implemented progressively

Characteristics:

• Not related to reactor types, generally applied
• Integrating probabilistic and deterministic analysis
• In accordance with basic safety principles
  ➢ Including defense-in-depth and safety margin
• Consistency, stability, predictability and flexibility
RISK-INFORMED DESIGN OF CAP1400

Risk-informed analysis of CAP1400 includes three parts:

- Detailed PSA model
- System reliability design
- Design improvement
DETAILED PSA MODEL OF CAP1400

A full scope PSA developed for CAP1400:

- Level 1, 2 and 3 analysis for internal events at power condition
- Level 1 PSA at low power and shutdown conditions
- Spent fuel pool PSA
- External events PSA
  - (Internal flooding, internal fire and seismic, etc.)
SYSTEM RELIABILITY DESIGN OF CAP1400

- Reliability target allocation
- System reliability prediction
- Adjustment of allocated reliability target

![Flowchart showing the process of system reliability design and verification]

1. Top level safety goals (CDF and LRF)
2. Develop the preliminary PSA model
3. Allocate preliminary systematic level reliability target
4. Detailed system design
5. System reliability prediction, based on system design
6. Whether the system reliability meets allocated system target?
   - Yes: The safety can be improved further?
     - Yes: Design improvement (see FIG. 2)
     - No: Design can be improved?
       - Yes: Adjust the allocated system reliability target
       - No: End
   - No: End
DESIGN IMPROVEMENTS OF CAP1400

Determination of improvement suggestions to reduce risk:

- Initiating events review
- Accident sequences review
- Minimal cutsets review
- Importance review

Final improvement plan:

- Communication with designers
- Cost-benefit analysis
- Expert judgment

Diagram:

1. Develop detailed plant PSA model
2. Analysis results and risk insights
   - Initiating events review
   - Accident sequences review
   - Minimal cutsets review
   - Importance review
3. Determine improvement suggestions to reduce risk
   - Communicate with designers
     - Feasible
       - Cost-benefit analysis
         - Feasible
           - Expert judgement
             - Feasible
               - Improvement specification
                 - Meets safety/design goals?
                   - Yes: Ultimate improvement plan
                   - No: Seek other improvement suggestions
4. Implement plan

Expert judgement:

- Improvement specification
- Not feasible
- Feasible
- Not feasible
- Feasible
EXAMPLE OF CAP1400 SYSTEM RELIABILITY ALLOCATION

Based on:

- System characteristics of CAP1400
- Experience of AP1000

System reliability prediction meeting top level safety goals
EXAMPLE OF CAP1400 SYSTEM RELIABILITY ALLOCATION

- system reliability goals (considering all factors)
- system reliability goals (not considering components of the system)
EXAMPLE OF CAP1400 DESIGN IMPROVEMENTS

Problems:

• Fire-induced risk of CAP1400 is significant
• Potential fire risk needs to be reduced

VEWFDS:

• Extensively applied for fire protection of telecommunication facilities
• Detecting fire initiating process
EXAMPLE OF CAP1400 DESIGN IMPROVEMENTS

Improvement suggestion:

• Addition of Very Early Warning Fire Detection System (VEWFDS)
EXAMPLE OF CAP1400 DESIGN IMPROVEMENTS

Safety:

CDF Proportion without VEWFDS

- Internal Events: 46.8%
- Internal Fire: 48.4%
- Seismic: 37.4%
- High Winds: 57.0%
- Internal Flooding:

CDF Proportion with VEWFDS

- Internal Events: 37.4%
- Internal Fire: 57.0%
- Seismic: 48.4%
- High Winds: 46.8%
- Internal Flooding:
EXAMPLE OF CAP1400 DESIGN IMPROVEMENTS

- Cost to install VEWFDS relatively low

Economy:
- Cost to install VEWFDS relatively low

Expert judgment:
- Approved

Internal Fire CDF : 32%↓
Total CDF : 15% ↓
EXAMPLE OF CAP1400 DESIGN IMPROVEMENTS

Other improvements include:

• Increase valve blowdown rate of ADS-4 and IRWST water level
• Increase the diameter of cavity flooding lines
• Improve the junction boxes of valves to against spray and flood
• Improve the fire evacuation door to against flood
SUMMARY

• Risk-informed design applied in CAP1400
• Risk-informed analysis of CAP1400 include three parts:
  ➢ Developing detailed PSA model
  ➢ System reliability design
  ➢ Design improvement
• Applicable and feasible suggestions optimize plant design
• The practice of risk-informed design in the new plant provides good experience for further application
THANK YOU