Lessons Learned from the Fukushima Dai-ichi Accident and Responses in Regulatory Requirements

Toyoshi Fuketa
Nuclear Regulation Authority

NRA, Japan
Nuclear Regulation Authority

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Introduction

- ✓ TEPCO's Fukushima Dai-ichi accident revealed the weakness of the foregone regulatory requirements, e.g.
  - Insufficient design provisions against tsunami,
  - Unpractical management measures under severe accident conditions, and
  - Insufficient provision for accidents far-exceeding the postulated design conditions.
- ✓ We re-realized the importance of the Defense in Depth (DiD) approach in design and preparations of countermeasures against beyond design basis accidents (b-DBAs).
- ✓ We learned from the accident that we must evaluate in advance the potential and consequences of a wide spectrum of internal and external initiators, including earthquake, tsunami, volcanism, aircraft crash, fire, terrorist attack, etc.

1. Prevention of SSCs failures

- ✓ The Fukushima Dai-ichi accident revealed vulnerability of structures, systems and components (SSCs) against extreme loads and conditions caused by some specific internal/external initiators. The NRA, accordingly, enhanced design requirements significantly.
- ✓ Due considerations are required for all the significant internal and external initiators.

1. Prevention of SSCs failures (cont'd)

- ✓ Re-evaluation of external hazards is also requested, particularly for natural phenomena, based not only on historical records but also on expert judgment to cover very rare events.
- ✓ As for earthquakes, more stringent criteria are prepared for active faults, more precise methods are provided for design-basis ground motions, etc.
- ✓ As for tsunami, more comprehensive methods are required for defining design-basis tsunami, covering possible earthquakes or other natural hazards, e.g., landslides in the ocean bed, as causes of tsunami based on national and international experiences, and countermeasures such as coastal levee and watertight doors are required.

2. Measures to Prevent CCFs

- ✓ The new requirements extend design-basis events and strengthen protective measures against natural phenomena and other initiators which may lead to common cause failures (CCFs).
- ✓ They put a particular importance in due consideration to ensure diversity and independence, i.e., shift of emphasis from “redundancy centered”.
- ✓ Diversity of operating mechanisms, e.g., diesel and gas turbine generators, motor-driven and diesel-driven pumps, is important as well as physical separation.

2. Measures to Prevent CCFs (cont'd)

- ✓ Safety-related system trains shall be
  - located at different elevations and/or different areas,
  - compartmentalized by installing bulkhead, or
  - distanced enough from each other.

  Mobile equipment shall be
  - stored in different locations, which are not easily affected by external initiators including intentional aircraft crash, and
  - easily and surely connectable to the target system by preparing spatially-dispersed multiple connecting ports.

3. Prevention of Core Damage

- ✓ In the new requirements by the NRA, the definitions of some DBAs are changed. Design provision is now required against prolonged SBO and LUHS.
- ✓ Also required is provision against some b-DBAs involving multiple failures, including anticipated transient without scram (ATWS), loss of core cooling, and loss of reactor depressurization.
- ✓ The new regulation requires licensees to validate the effectiveness of countermeasures against b-DBAs.

4. Mitigation of Severe Accident

- ✓ In the Fukushima Dai-ichi accident, many attempts to activate the AM measures were unsuccessful due to the aggravated plant conditions, such as loss of power, loss of control air, aftershocks, and high radiation. The feasibility and effectiveness of AM measures are now strictly examined in licensing processes.
- ✓ Containment cooling/depressurization system to be used in severe accident conditions, e.g., filtered venting system, shall be installed to prevent the containment failure due to over-pressurization and to minimize the radioactive consequences.

5. Emergency Preparedness

- ✓ The guidelines existed before the accident primarily and excessively relied on code predictions on source terms and radionuclide diffusion. Projected dose and dose that has been received are not measurable quantities and cannot be used as a basis for quick actions in an emergency. The new guidelines by the NRA accordingly introduce operational criteria (values of measurable default quantities or observables, such as the emergency action level, EAL, and the operational intervention level, OIL) as a surrogate for the generic criteria for undertaking different protective actions and other response actions.
- ✓ The new guidelines also define requirements on roles and functions of off-site emergency response centers, execution of nuclear emergency drills, etc.

6. Continuous Improvement of Safety

- ✓ The amended “Reactor Regulation Act” stipulates licensees’ responsibility for “safety improvement” and requires licensees to conduct “self-assessment for safety improvement” periodically.
- ✓ This framework strongly encourages licensees’ initiatives towards continuous improvement of safety by requesting licensees to prepare the final safety analysis report which provides “as-built” or “as-is” plant description and to update it when major design modifications or procedural changes take place.

6. Continuous Improvement of Safety (cont'd)

- ✓ Licensees are also requested to carry out the periodic safety review (PSR) to incorporate the state-of-the-art knowledge into the plant design, operation and maintenance activities.
- ✓ In addition, it is required to conduct level 1 and 2 probabilistic risk assessments (PRAs) periodically for both internal and external initiators including hazard re-evaluation to demonstrate the effectiveness of the plant modifications.

Closing Remarks

- ✓ In the light of the Fukushima Dai-ichi accident, the NRA developed the new design requirements and established the new regulatory framework to ensure the nuclear power plant safety.
- ✓ The NRA continues to address the lessons learned from the Fukushima Dai-ichi accident, keeps updating regulatory requirements where appropriate, and never becomes complacent.

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