Consideration of Uncertainty in New Regulatory Requirements

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1. Uncertainties related to severe accident measures

- If an accident progresses to the point where the primary containment vessel is damaged, uncertainties related to the manner of the accident, such as the damaged state of the primary containment vessel as well as nuclides, chemical forms, quantity and release route of the released radioactive materials, become extremely large, which makes it practically impossible to make all assumptions even based on latest technical knowledge.

- Therefore, the manner of the accident cannot be identified in advance in the first place, and it is not possible to require setting success criteria of measures and assess effectiveness of measures.

- Additionally, it is extremely unreasonable as a regulatory requirement to require limitless measures for all events including events that have very low possibility of occurring and whose manner is difficult to be identified in advance.

- Furthermore, requiring measures that are based on specific assumptions regarding the manner of the accident in such situation with large uncertainties has the risk of causing difficulty in accident response such as measures prepared based on the requirements not functioning in an actual accident due to differences between the actual accident and assumed conditions. Rather, it is reasonable as a regulatory requirement to require implementing flexible measures according to the situation.

- Therefore, for measures in case an accident progresses to the point where the primary containment vessel is damaged, while the New Regulatory Requirements require equipment with necessary functions to suppress the spread of radioactive materials and development of frameworks and procedures to enable flexible response according to the situation using such equipment, it does not require effectiveness assessment of such measures such as quantitative assessment of suppression of spread of released radioactive materials.

2. Formulation of design basis ground motion and uncertainties ①

(Example) Seismic motion formulated by identifying the epicenter of each site

◆ Various uncertainties associated with the process of formulating design basis ground motion need to be considered using appropriate methods such as combining epistemic uncertainty and aleatory uncertainty, upon analyzing dominant parameters* considered to have a large impact on seismic motion assessment of the site.

*Numerical figures of fault properties such as fault length, width, inclination angle and stress drop. Such parameters are set based on active fault assessment results, and those with relatively large impact on the solution when considering uncertainties are regarded as "dominant parameters".

◆ In specific, multiple earthquakes that are predicted to have a large impact on the site (hereinafter referred to as "earthquake for review") are selected for inland crustal earthquakes, interplate earthquakes and intra-oceanic plate earthquakes, and it is required to formulate seismic motion assessment based on response spectrum considering uncertainties* and seismic motion assessment using fault models, incorporating the propagation characteristics of seismic waves to the surface of the released base, for each of the selected earthquake for review.

*The seismic motion assessment process involves uncertainties in various parameters such as length of epicenter fault and location and size of asperities. Seismic motion is assessed by changing such parameters (e.g. extend the length of epicenter fault, move asperity location closer to the site) upon analyzing dominant parameters which are considered to have a large impact on seismic motion assessment of the site.

2. Formulation of design basis ground motion and uncertainties ②

(Example) Seismic motion formulated without identifying the epicenter

- "Seismic motion formulated without identifying the epicenter" is required to be formulated by setting the response spectrum according to geotechnical properties of the site, upon collecting observation records near the epicenter obtained for past inland crustal earthquakes where it is difficult to relate the epicenter to an active fault and considering various uncertainties based on this.

(Example) Seismic motion assessment when the epicenter is extremely close to the site

- If the epicenter is extremely close to the site for inland crustal earthquakes, it is required to formulate design basis ground motion with more detailed review.
- This is because of uncertainties involved in the assessment method, due to heterogeneity of the subsurface structure possibly having a greater impact on seismic wave propagation characteristics and not having enough observation records of inland crustal earthquakes as their recurrence period is long.
- In specific, for example, it is required to review in detail the validity of the shape and location of the epicenter model, positional relation to the site and established facilities, and validity of setting epicenter characteristic parameters, upon considering the entire fault with displacement on the ground surface, and conduct assessment with attention to applicability of the assessment method based on such review results.
- In this case, it is also required to assess more in detail the impact of various uncertainties on seismic motion assessment, and design basis ground motion with enough margin based on scientific and technical knowledge related to characteristics of seismic motions in the extremely vicinity of the epicenter.

3. Seismic design of safety functions and uncertainties

In formulating design basis ground motion,

① Determine the location and length of the fault based on various geological surveys

② Conduct seismic motion assessment based on response spectrum

③ Also conduct seismic motion assessment with the method using fault models

to formulate seismic motion formulated by identifying the epicenter of each site.

Also separately,

④ Formulate seismic motion formulated without identifying the epicenter

Since each of the process requires conducting a conservative assessment by respectively setting parameters considering uncertainties, design basis ground motion to be formulated inevitably becomes conservative.

In addition, conservative margin is also required in the seismic design phase which is the phase to analyze seismic response of structures when actual seismic motions is transmitted to buildings, structures, equipment, pipes, etc. (response analysis) and design such structures to withstand such analysis results.

4. Formulation of design basis tsunami and uncertainties

Basic concept for the formulation of design basis tsunami

According to cases of tsunami around the world and the mechanism of tsunami generation, earthquakes that generate strong tremors and large tsunami due to large slip at plate boundaries and tsunami earthquakes and crustal earthquakes in the sea that occur near the oceanic trench and generate large tsunami without strong tremors, as well as collapse of volcanic edifice and landslides are major factors that cause tsunami. Thus, the following is considered as factors to cause tsunami:

- Interplate earthquake
- Intra-oceanic plate earthquake
- Crustal earthquake due to active faults in the sea
- Landslide and slope failure on land and at the bottom of the sea
- Volcanic phenomena (eruption, collapse of volcanic edifice, caldera sinking, etc.)

Multiple factors predicted to have a large impact on the site are selected. Additionally, combinations of interplate earthquakes and other earthquakes, or earthquakes and landslides or slope failure are considered, based on geological background of the site in relation to tsunami generation factors and relevance of tsunami generation factors.

4. Formulation of design basis tsunami and uncertainties

Validity of formulation of design basis tsunami used in tsunami resistance design

- It is required to formulate design basis tsunami by conducting numerical analysis considering uncertainties, with assumptions from seismological aspects, such as seafloor topography, geological structure and seismic activity from the wave source sea area to the site vicinity, based on latest scientific and technical knowledge.

Consideration of uncertainties in the process of formulating design basis tsunami

- In order to include enough margin for tsunami resistance design, it is required to use appropriate methods in considering uncertainties associated with the process to formulate design basis tsunami, by fully taking into account uncertainty factors of wave source characteristics considered to have a large impact on the formulation of design basis tsunami, such as fault location, length, width, strike, slip amount, slip angle, slip distribution, rupture initiation point and rupture propagation speed, and uncertainties resulting from the degree of such factors and differences in the approach and interpretation of such factors.

5. Assumption of pyroclastic fall deposits and uncertainties

◆For regulations related to airborne pyroclastic fall deposits, it is necessary to consider the possibility of high concentration airborne pyroclastic fall deposits arriving and blocking the intake filters of emergency diesel generators, as it was observed from the observation data obtained for the eruption of Mount St. Helens in 1980 according to the previously mentioned CRIEPI report and AIST report.

◆Although there are large uncertainties, concentration and duration of airborne pyroclastic fall deposits used for the assessment of whether functions of safety facilities can be maintained by replacing filters are set based on comprehensive and engineering judgment, taking into account estimates based on the estimation method using the amount of deposition assuming ash fall duration and estimation method using numerical simulation.

Conclusion: Relationship between the New Regulatory Requirements and uncertainties (personal opinions)

- The New Regulatory Requirements require a flexible response as uncertainties are large especially in the phase that leads to primary containment vessel damage after the fourth layer of the defense in depth (DiD).
- On the other hand, measures against natural phenomena and fire, etc., require conservative design considering various uncertainties.
- It can be understood as an intention to reduce uncertainties included in plant response after the fourth layer of DiD as much as possible in design.
- The point of utilizing risk information, it is important to use indicators considering the frequency of the events. However, it is also important to avoid unnecessarily increasing uncertainty as long as it is possible to manage it.

  *It could be argued that it should be addressed because it has a large impact, even if it occurs at low frequency.

- In this sense, looking back on TMI and the stuck pressurizer relief valve at Mihama Unit 2 these days when severe accident measures and anti-terrorism measures are attracting attention, focus should be renewed on how response to transients and design basis accident levels can be achieved. Considerations to uncertainties will encourage a return to such perspective.