

Application of MACCS in S/NRA/R

Chihiro SUZUKI

Regulatory Standard and Research Department
Secretariat of Nuclear Regulation Authority
(S/NRA/R)

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Objectives of Level 3 PRA research in S/NRA/R

1. Provide technical background for discussion of safety goals.
 - ✓ Identify dominant accident sequences and its individual risks.
2. Provide support for formulation and revision of the Guide for Emergency Preparedness and Response.
 - ✓ Examine the effect of evacuation for typical plants in Japan.

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Discussion of Safety Goals

- The results of the studies in the former Nuclear Safety Commission¹⁾²⁾ will be the basis for the discussion of safety goals in NRA.
- From the viewpoint of environmental protection, the occurrence frequency of accidents resulting in Cs-137 release over 100 TBq should be less than approximately 10^{-6} per reactor year.
- The safety goals are not to be used for direct judgment on whether an individual NPP is safe enough or not, but are to be used to judge the adequacy of the regulation.
- NRA will continue to discuss safety goals for continuous safety improvement.

Commissioner Meeting of Nuclear Regulation Authority, April 10, 2013

[Proposal of qualitative goal in the former study¹⁾]

"The possibility of health effects to the public caused by utilization of nuclear power should be limited to the level not to cause a significant increase in the public risk."

1) Special Committee of Nuclear Safety Commission, "Interim Report on the Investigation and Review on Safety Goals", December 2003.
2) Special Committee of Nuclear Safety Commission, "Performance Goals for Light Water Nuclear Power Reactor Facilities", March 2006.

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Outline of research

- Introduction of MACCS (1993) and MACCS2 (1997)
- Preparation of Japanese site data
- Level 3 PRA for BWR and PWR plants in Japan
 - Technical Report
 - Study on Level 3 PSA for internal events (BWR), JNES/SAE05-003, June 2005
 - Study on Level 3 PSA for internal events (PWR), JNES/SAE05-008, August 2005
 - The result of the studies had been utilized in the derivation of performance goals¹⁾.
- Development of methodology for multi-unit
- Incorporation of revised evacuation models
 - ✓ The EPR Guide was revised in response to Fukushima Dai-ichi Accident.
 - ✓ Phased evacuation of the new guide was applied in MACCS calculation.

1) Special Committee of Nuclear Safety Commission, "Performance Goals for Light Water Nuclear Power Reactor Facilities", March 2006. 4

Development of Methodology for Multi-unit

Background

- In evaluating risks for earthquakes, simultaneous accidents at multiple units in the same earthquake need to be considered.

Situation in Japan

- Most NPPs have multiple units, distances from each unit to its site boundary are relatively short, and population density around NPP is relatively high.
- Multiple units were actually damaged in the accident at TEPCO's Fukushima Dai-ichi Nuclear Power Plant.

Approach

- Radiological consequence
 - ✓ Calculation of downwind concentration at a receptor due to releases from additional units and its wind direction appearance frequencies.
 - MACCS2 modification
- Release frequency
 - ✓ Calculation of Containment Failure Frequency required for each combination of accident sequences.
 - FreCTool (Frequency Calculation Tool for Seismic Level 3 PRA)

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Development of Methodology for Multi-unit

Reference

[Frequency]
 Response to ground motion differ
 → Conditional CDF/CFR differ
 → Release frequency of each source term differ

- ✓ Radiological consequence depend on combination of accident sequences.
- ✓ Release frequency per combination of accident sequences is required.

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Development of Methodology for Multi-unit

Calculation of concentration

1. The location of receptors are defined based on mesh distances and direction of a base unit.
2. Concentration due to releases from additional units are calculated at the receptor.
3. Because concentration is calculated only at specified mesh distances, concentration from an additional unit is calculated by liner-interpolation.

Reference) Japan Nuclear Energy Safety Organization, "Development of Level 3 PSA methodology", JNES/SAE06-005 (2006) (in Japanese) 7

Development of Methodology for Multi-unit

Calculation of wind direction appearance frequency

Ex. In the case where base unit "a" and additional unit "b" is located as shown in the figure,
Wind direction appearance frequency f_b toward shaded area (north direction of a base unit) from an additional unit "b" is calculated as follows:
$$f_b = f_N \left(Q_N / \frac{\pi}{6} \right) + f_{NNW} \left(Q_{NNW} / \frac{\pi}{6} \right)$$

- f_N : north wind frequency
- f_{NNW} : north-northwest wind frequency
- Q_N : angle in radians that north direction of unit "b" and shaded area overlaps
- Q_{NNW} : angle in radians that north-northwest direction of unit "b" and shaded area overlaps

Calculate wind direction appearance frequency of additional units by repeating the calculation above for all meshes.

Reference) Japan Nuclear Energy Safety Organization, "Development of Level 3 PSA methodology", JNES/SAE06-005 (2006) (in Japanese) 8

Development of Methodology for Multi-unit

Test calculation

Case 1

○ Base unit

○ Additional unit

Case 2

○ Base unit

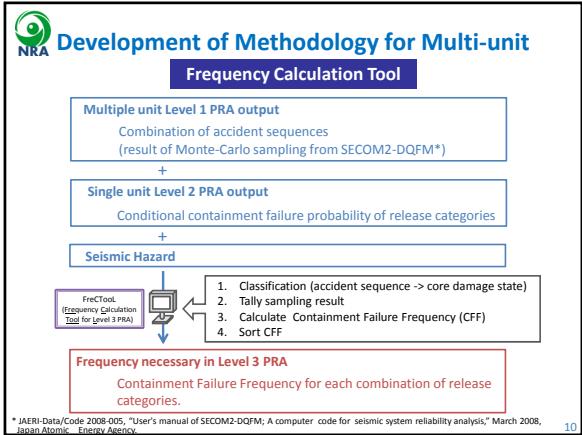
○ 300 m

○ Additional unit

Same source term (BWR-5, TW-6) was used for both Base unit and Additional unit.
*Expected concentration of each direction is an output only for calculation check.

Distribution of expected air concentration of I-131 at receptors 0.35 km from the base unit

Reference) Japan Nuclear Energy Safety Organization, "Development of Level 3 PSA methodology", JNES/SAE06-005 (2006) (in Japanese) 9



Summary

- The purposes of Level 3 PRA study in S/NRA/R are to provide technical background for discussion of safety goals and to provide support for formulation and revision of the EPR Guide.
- For these purposes, MACCS2 was introduced.
- Analysis results were utilized in the derivation of performance goals.
- Methodology for multiple unit site was developed.

Ongoing Research

- PRA on external events
 - ✓ Multiple unit PRA
 - ✓ PRA with Accident Management
- Introduction of OSCAAR*
 - ✓ Modification of OSCAAR and preparation of latest site data (commissioned to JAEA), mainly intended for use in supporting emergency planning.

*OSCAAR : Level 3 PRA code developed by Japan Atomic Energy Agency
