# Review of Accident Screening Criteria for Evaluating SMR EPZ

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## 1. Introduction

The U.S. Nuclear Regulatory Commission (NRC) published the SECY-11-0152 report in 2011 [1]. The report includes the NRC's intention to develop a technology-neutral, dose-based, and consequence-oriented emergency preparedness for Small Modular Reactor (SMR). To get ahead of regulation, Nuclear Energy Institute (NEI) also published a white paper for Emergency Planning Zone (EPZ) of SMR [2]. The white paper presents a general methodology and accident screening criteria for SMR EPZ and should be reviewed thoroughly to establish a scalable EPZ. This paper covers NEI's methodology for selecting and evaluating accident scenarios to scale SMR EPZ. In addition, it should be noted that this paper does not show KHNP position.

## 2. Accident Screening Criteria

A nuclear power plant is surrounded by several zones. For the plant security, the PA is established. In addition, licensing for nuclear power plant siting is required to evaluate EAB, LPZ, and PCD, and emergency preparedness is required to establish and operate PAZ and UPZ [3, 4]. The PAZ and UPZ are subparts of current EPZ. The several zones with acronym are conceptually presented in Fig. 1.

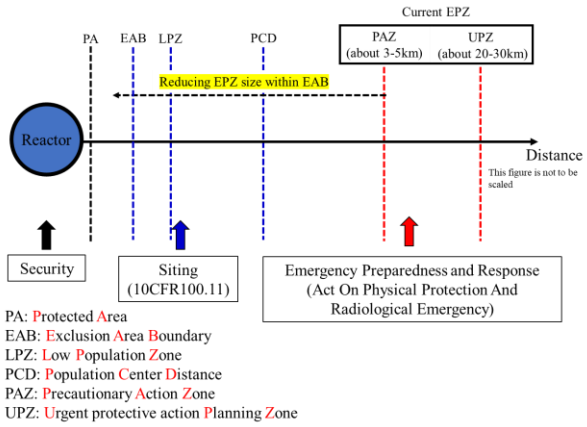


Fig. 1. Conceptual comparison of several zones

Most SMR applicants in the world pursue the reduction of EPZ within EAB. To achieve this goal, three kinds of accident scenario in Fig. 2 are considered in calculating EPZ. The three criteria for SMR EPZ are described in the following subsections.

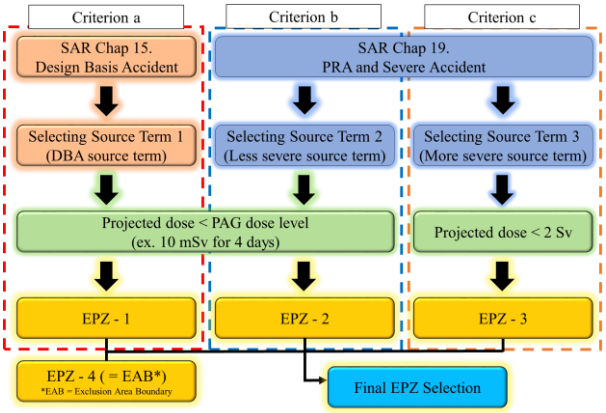


Fig. 2. Flowchart of evaluating and selecting SMR EPZ

### *2.1. Criterion a*

The 'criterion a' is that the EPZ should encompass those areas in which projected dose from DBAs exceed the PAGs.

#### 2.1.1. Accident scenario selection for *criterion a*

Selecting scenario for criterion a is relatively simple because Design Basis Accident (DBA) scenarios from Safety Analysis Report (SAR) chapter 15 is utilized. However, conventional Loss of Coolant Accident (LOCA) source term based on regulatory guide 1.183 might be different in SMRs [5].

#### 2.1.2. Source term evaluation for *criterion a*

No additional source term evaluation for criterion a is performed. The selected source term is utilized as a form of release amount of radioactive material at a specific time, which is traditional source term analysis in chapter 15 of SAR. If the existing source term is hard to be applied due to the conservative assumptions, another DBA source term should be developed for SMR EPZ.

#### 2.1.3. Consequence analysis for *criterion a*

The EPZ boundary consequence analysis should be performed by referring to the State-of-the-Art Reactor Consequence Analyses (SOARCA) project [6]. The SOARCA project considers various exposure pathways and best-estimate calculation, which is different from dose calculation in chapter 15 of SAR. The dose

calculation in the chapter 15 is based on regulatory guide 1.145, resulting in conservative and simple dose calculation [7]. In other words, the best-estimate consequence analysis is required with the DBA source term.

2.1.4. Projected dose vs. Dose limit for *criterion a*

In the EPZ, the projected dose of DBA source term shouldn't exceed the Protective Action Guide (PAG) dose limit. The PAG dose limit is ranged from 10 to 50 mSv of Total Effective Dose Equivalent (TEDE). The mean and 95 percentiles of TEDE over all weather trials are compared with 10 mSv and 50 mSv, respectively.

*2.2. Criterion b*

The 'criterion b' is that the EPZ should encompass those areas in which consequences of less severe core melt accidents could exceed the PAGs.

2.2.1. Accident scenario selection for *criterion b*

The accident scenario frequencies are utilized for the criterion b; therefore, the selection process is more complicated than criterion a. The scenario selection is accomplished using Probabilistic Safety Assessment (PSA), which is similar to the process in the SOARCA project [6]. The process of accident scenario selection is summarized as follows.

- Initial selection with mean Core Damage Frequency (CDF) > 1E-6 per plant year
- Even if the frequency of intact containment scenario is below 1E-6, it should be included.
- Basemat Melt-Through (BMT) accidents should be included if they are not precluded by design [8].

2.2.2. Source term evaluation for *criterion b*

The fully integrated and advanced software is required for evaluating source term for criterion b. The representative software is MELCOR and MAAP used in the Level 2 PSA. In addition, credit for operator mitigation actions is limited to Emergency Operating Procedure (EOP).

The consequence analysis and dose comparison for criterion b is same as for criterion a.

*2.3. Criterion c*

The 'criterion c' is that the EPZ should be of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core melt accidents as BDBA (Beyond Design Basis Accident).

2.3.1. Accident scenario selection for *criterion c*

Accident scenarios for criterion c are also selected by PSA results, and the selection process is similar to the SOARCA project [6]. The process of accident scenario selection is summarized as follows.

- Initial selection with mean CDF > 1E-8 per plant year
- Use of radionuclide release frequency rather than CDF
- Consideration of potential impact of sharing system
- Consideration of extreme seismic and other external hazards

2.3.2. Source term evaluation for *criterion c*

For the criterion c, the MELCOR and MAAP are also used in evaluating source term. In addition, Severe Accident Mitigation Guidelines (SAMGs) and Extensive Damage Mitigation Guidelines (EDMGs) are considered in operator mitigation actions. Moreover, the release characteristic of multi-module accident scenarios is expected to be complex, therefore, their dynamic characteristic should be considered in source term evaluation.

2.3.3 Consequence analysis and dose limit for criterion c

The consequence analysis is similar to the previous criteria and a whole-body acute dose of 2 Sv is considered because of accident severity. In addition, the dose exceedance probabilities by distance is presented as Complementary Cumulative Distribution Function (CCDF) [8], and they are weighted by scenario frequency. The EPZ size is determined at which the total probability is below 1/1000. The example of CCDF is presented in Table I and Fig. 3.

Table I: Example of weighting frequency for criterion c

| Scenario | S1 | S2 | S3 | | Total |
|---|---|---|---|---|---|
| Frequency | f1 | f2 | f3 | | F_tot = f1 + f2 + f3 |
| Fraction | F1=f1 /(f1+f2+f3) | F2=f2 /(f1+f2+f3) | F3=f3 /(f1+f2+f3) | | 1 |
| | | | | | |
| Distance | Conditional Probability of Exceeding 2 Sv | | | | |
| X1 | p1_1 | p2_1 | p3_1 | | p1_1·F1 + p2_1·F2 + p3_1·F3 |
| X2 | p1_2 | p2_2 | p3_2 | | p1_2·F1 + p2_2·F2 + p3_2·F3 |
| X3 | p1_3 | p2_3 | p3_3 | | p1_3·F1 + p2_3·F2 + p3_3·F3 |
| X4 | p1_4 | p2_4 | p3_4 | | p1_4·F1 + p2_4·F2 + p3_4·F3 |

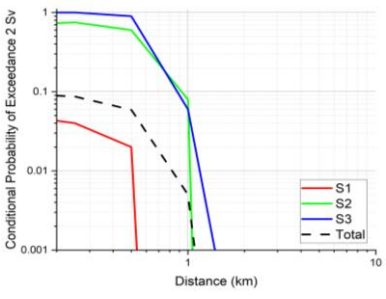


Fig. 3. Dose exceedance probability by distance (example)

### *2.4. Discussion*

In Korea, a single boundary of UPZ is used without considering the individual commercial reactor characteristic. Unlike large commercial reactors, the SMR EPZ should be set at an appropriate level considering safety features of the SMR. Various accident source terms including DBA and BDBA can be used in evaluating SMR EPZ. The BDBA source term information can be obtained by PSA, which can be also applied into non-light water reactors to be developed in the future. Such regulatory issues of SMR EPZ are hopefully expected to be discussed in the pre-application review between industry and regulatory bodies.

## 3. Conclusion

Most SMR applicants in the world pursue the reduction of EPZ. In order to reduce the SMR EPZ, the NEI methodology and accident screening criteria has been reviewed. The NEI methodology for SMR EPZ is based on both DBA and PSA accident scenarios. In order to reduce EPZ of iSMR, the NEI methodology should be examined in detail in the future.

## REFERENCES

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