A Study for Establishment of a Korean SMR EPZ Based on U. S. SMR Approach

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1. Introduction

Recently, in U.S., by the NRC regulation [1] and industry guide such as NEI [2], a scalable emergency planning zone (EPZ) is accepted for small modular reactors (SMRs) less than 1,000 Mwt. According to this friendly atmosphere, a new plume exposure pathway EPZ of NuScale SMR, which is near site boundary size, is submitted to NRC for approval [3]. The EPZ setup methodology adapted in the NuScale is the methodology suggested in the NEI guidance [2].

In Korea, several SMRs, such as SMART [4], BANDI-60s [5], etc., are being developed. For the EPZ setup for one of Korean SMRs, the NEI methodology for EPZ distance is applied, and this paper describe the results.

2. Methods

2.1 EPZ Setup Methodology of NEI

The NEI EPZ setup methodology [2] adapted by NuScale has the following characteristics;

- The EPZ is scalable whose plume exposure pathway can be less than 10 miles which is almost fixed for the large commercial reactors.
- The EPZ is determined by the criteria of NUREG-0396 [6]. However, the determination between less and more severe accidents is depend on whether the containment is intact or not. (Rule 1)
- For severe accidents, dose-distance results are aggregated using accident sequence frequency information derived from PSA. (Rule 2)

In USA, NUREG-0396, which was issued in 1978 before TMI accident, is still backbone in the current EPZ regulation.

The following three criteria suggested in NEI [2, 3] are based on the those of NUREG-0396, but are slightly modified by using acceptable assumptions for the SMR.

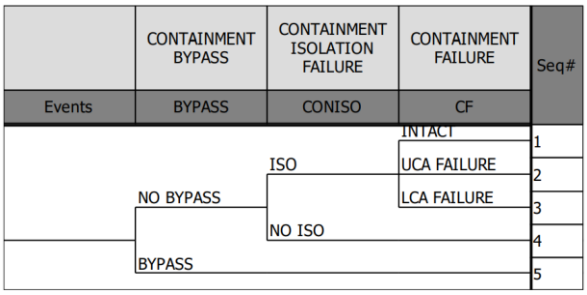
Criterion a: The distance at which dose does not exceed either a 1 rem TEDE (Total Effective Dose Equivalent) at mean weather conditions (or a 5 rem TEDE criterion at 95th percentile weather conditions) for design-basis source term. (Exposure duration of 4 days)

Criterion b: The distance at which dose does not exceed either a 1 rem TEDE criterion at mean weather conditions (or a 5 rem TEDE criterion at 95th percentile weather conditions) for less severe accident sequences. (Exposure duration of 4 days)

Criterion c: The distance at which the conditional probability of exceeding 200 rem whole body acute dose drops below 1E-3 for more severe accident sequences. (Exposure duration of 1 day)

2.2 EPZ for a Korean SMR

After the level 2 PSA of a Korean SMR, source terms are calculated according to five source terms categories (STC) shown in Fig. 1.



UCA: Upper Containment Area
LCA: Lower Containment Area

Fig. 1. Source Term Category Logic Diagram

In Fig. 1, source term category 1 (STC1) means 'no containment failure'. STC2, STC3, STC4, and STC5 indicate 'UCA failure', 'LCA failure, 'containment isolation failure' and 'containment bypass', respectively.

By the *Rule 1* of *Section 2.1*, STC1 is treated as a less severe accident sequence since the containment is

intact. STC2, STC3, STC4, and SCT5 are treated as more severe accident sequences.

Containment failure frequency for each STC was calculated. However, in Table 1, the containment failure frequency is not shown, but only its fraction is given since frequency fraction is enough for this paper.

STC	Containment Failure Mode	Freq. Fraction	Remark
1	NO CF		Less Severe
2	CF: UCA Failure	10 %	More Severe
3	CF: LCA Failure	52 %	
4	CF: Isolation Failure	0 %	
5	CF: Bypass Failure	38 %	

Table 1 Containment failure freq. of the Korean SMR

3. Results

3.1 EPZ Distance by Criterion a

With MACCS2 code [7], the doses received after station blackout (SBO) design basis accident (DBA) are calculated at different distances from the Korean SMR, and the Criterion *a* of *Section 2.1* was applied with mean and 95th percentile weather conditions. Conditional probability of 1 rem exceedance vs distance curve is shown in Fig. 2. In Fig. 2, when mean weather condition is used, the EPZ distance would be 200 m. Also, the result of 95th percentile weather condition with 5 rem threshold is not beyond 200 m.

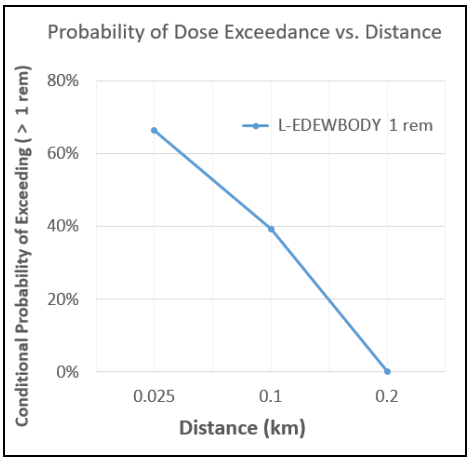


Fig. 2. Probability of 1 rem exceedance vs distance curve in SBO DBA case

3.2 EPZ Distance by Criterion b

Since less severe accident sequence is only STC1, the *Rule 2* of Section 2.1 is not necessary. The *Criterion b* of *Section 2.1* was applied with mean and 95th percentile weather conditions. Thus, in Fig. 3, if mean value is used, EPZ size could be conservatively determined as 300 m. Also, the result of 95th percentile weather condition with 5 rem threshold is similarly 300 m.

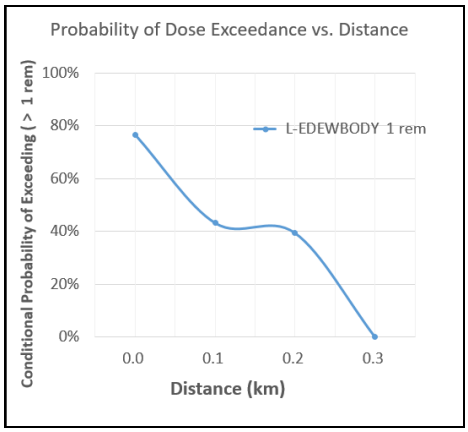


Fig. 3. Probability of 1 rem exceedance vs distance curve in STC1 less severe accident case

3.3 EPZ Distance by Criterion c

Since more severe accident sequences are STC2, STC3, STC4, and STC5, the *Rule 2* of *Section 2.1* is used. Since 'red marrow acute dose' is used instead of 'whole body acute dose' in NEI guidance [2], the 'red marrow acute dose' is used in *Criterion c*. The probability of 200 rem dose exceedance vs distance is in Table 2.

Table 2. Calculation of probability of dose exceedance

		Sequences			
		STC2	STC3	STC5	Total CDF
	CDF	10%	52%	38%	1.00E+00
	Distance (km)	Cond. Prob. of exceeding 200 rem for sequence i at distance j			Total Cond. Prob. of exceeding 200 rem at distance j
1	0.025	5.03E-01	5.56E-01	1.00E+00	7.17E-01
2	0.1	2.81E-03	2.81E-03	1.00E+00	3.77E-01
3	0.2	0.00E+00	0.00E+00	1.00E+00	3.75E-01
4	0.3	0.00E+00	0.00E+00	1.00E+00	3.75E-01
5	0.4	0.00E+00	0.00E+00	4.30E-01	1.61E-01
6	0.5	0.00E+00	0.00E+00	4.30E-01	1.61E-01
7	0.6	0.00E+00	0.00E+00	4.08E-01	1.53E-01
8	0.7	0.00E+00	0.00E+00	1.64E-01	6.16E-02
9	0.8	0.00E+00	0.00E+00	2.81E-03	1.05E-03
10	0.9	0.00E+00	0.00E+00	1.14E-04	4.28E-05

In Table 2, the conditional probabilities (given more severe accidents) of dose exceeding 200 rem whole body acute for each of the three sequences (STC4 is neglected since its frequency fraction is zero.) are given for ten distances from the reactor, 25 m to 900 m. The conditional probability of the dose exceeding 200 rem summed over all sequences at a given distance is in the right-hand column. From these values for the 10 distances in Table 2, a curve is plotted as shown in Fig. 4 and the distance at which probability drops below 1E-3 is determined, as an EPZ distance. In Fig. 4, the EPZ distance would be 800 m by aggregating the frequency fraction.

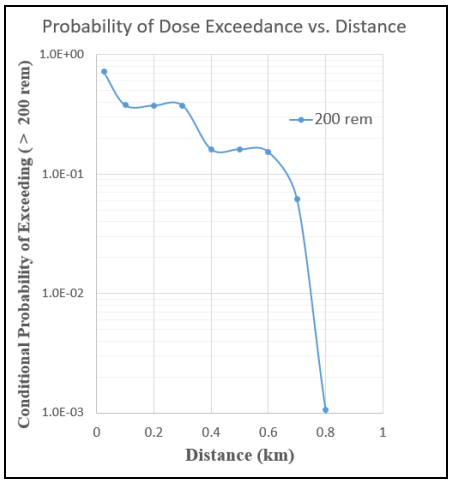


Fig. 4. Probability of 200 rem exceedance vs distance curve in more severe accident sequences case

3. Conclusions

The results of MACCS2 calculation show that the largest plume dose pathway EPZ distance for the Korean SMR is determined from the *Criterion c* for the most severe accident. The EPZ could be 800 m.

Even though a further study is required, it seems that the Korean SMR could use the site boundary EPZ where the Exclusive Area Boundary (EAB), the Low Population. Zone (LPZ), and EPZ are the same distance.

Acknowledgement

This work was supported by joint project funded by KAERI and K.A. CARE.

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