

A Review of Emergency Planning Zone (EPZ) for Establishment of SMART EPZ

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1. Introduction

The SMART reactor is a small size reactor (365 MWt) which will be installed in Korea or in Saudi Arabia. Since the SMART reactor is much smaller than commercial nuclear reactors, it is necessary to set up a reduced emergency planning zone (EPZ). Furthermore, the requirement for EPZ is different between IAEA and USA. After Fukushima Accident, the EPZ requirement in Korea was changed, roughly, from USA to IAEA. To export the SMART reactor to the world, the EPZ for the SMART reactor should be world-widely acceptable. Thus, to set up an adequate reduced EPZ for the SMART reactor, the regulatory history and requirements of EPZ in USA and IAEA are reviewed in this paper. And, EPZ for small modular reactors (SMRs) are also reviewed in this paper.

2. Methods

First of all, since EPZ is related to the site requirements, the site requirement will be discussed. Then, the history of EPZ in USA and IAEA will be discussed, and the safety goal will be mentioned.

2.1 Site Requirements

According to WASH-3 [1], there was a rule of thumb for the size of exclusion area of the nuclear reactor site. The rule of thumb was;

$$R = 0.01\sqrt{P} \quad (1)$$

where P is power of the nuclear reactor [kwh],

R is the exclusion area radius [miles],

and it was assumed that no containment was used, and that the exposed whole body dose was 300 R.

Thus, according to Eq. (1), if the reactor power is 30 MWt, then the exclusion area radius is 1 mile, and if 3000 MWt, then the radius is 10 miles. However, if we check the actual approved exclusion area radius during 1950's, the actual radius is 1/10 of the theoretical radius calculated by the rule of thumb, Eq. (1) because the utility wanted small exclusion area as well as reactor site near the center of a city by adopting a containment.

There were no regulatory criteria for the site approval during 1950's since the US government wanted for the submarine reactor (PWR) to be

commercially built as soon as possible, and the utilities wanted to build the reactor near the city.

The regulatory criteria for the site approval was prepared in 1960. In 1960's, the current site criteria such as exclusion area boundary (EAB), low population zone (LPZ), population center distance, were already prepared in 10 CFR 100 [2]. However, the integrated man-rem dose concept (4×10^6 man-rem as a maximum exposure integral) which was discussed before was no longer discussed [3].

2.2 EPZ History in USA

As the PSA technology was improved by WASH-1400 [4], the EPZ as a final defense-in-depth to mitigate an accident was prepared by NUREG-0396 [5] in 1978 before TMI accident. The following basic criteria suggested in NUREG-0396 [5] is still backbone in the current EPZ regulation, and in the EPZ for future reactors such as SMR.

Criterion 1: The EPZ should encompass those areas where the projected dose from design-basis accidents could exceed the EPA PAGs [6].

Criterion 2: The EPZ should encompass those areas where consequences of less-severe Class 9 (core-melt) accidents could exceed EPA PAGs.

Criterion 3: The EPZ should be of sufficient size to provide for substantial reduction in early severe health effects in the event of the more severe Class 9 accidents.

EPZ is defined for exposure pathways. The area within about 10 miles of the plant is referred to as the "Plume Exposure Emergency Planning Zone" (PEPZ). The PEPZ is the area of primary concern regarding potential exposures to the plume. Beyond the PEPZ, out to about 50 miles, there is ingestion exposure pathway where the principal concern is potentially contaminated foodstuffs. The area can be named as ingestion EPZ (IEPZ).

In 1980's, after NUREG-0396 decided that PEPZ should be about 10 miles, there were argues about 10 miles PEPZ. In 1985, Calvert Cliffs requested 2 mile PEPZ since the source terms established by WASH-1400 [4] were too high [7]. In 1986, Seabrook unit 1

requested 1 mile PEPZ to avoid the interference in emergency planning exercise of the neighbor state, Massachusetts [8]. Both requests were denied by NRC. In 1985, there was a 20 mile EPZ issue of Shoreham plant, and then 10 mile PEPZ of the plant was confirmed by using Shoreham PRA [9].

After Ref. [9] clearly showed PEPZ should be 10 miles, the 10 mile PEPZ requirement on the commercial reactors above 250 MWt has not changed for more than 30 years in U.S. Recently, scalable PEPZ for SMR is discussed, and which is in detail mentioned in the section 2.5 EPZ for SMR.

2.3 EPZ History in IAEA

In 1979, after TMI accident, IAEA had the first EPZ requirements which is the same US EPZ ones. However, since the requirements are just recommendation, many European countries had own different EPZ requirements.

After Chernobyl accident, IAEA enhanced the EPZ requirements since many European countries had experiences of being exposed to the radioactive plume of Chernobyl accident, 1986.

The EPZ of IAEA can be summarized in Table 1, and the PAZ, UPZ, and LPZ are defined as below [10]:

PAZ (precautionary action zone): *within which arrangements shall be made with the goal of taking precautionary urgent protective action, before a release of radioactive material occurs or shortly after a release of radioactive material begins, on the basis of conditions at the facility (such as the emergency classification) in order to reduce substantially the risk of severe deterministic health effects.*

UPZ (urgent protective action planning zone): *within which arrangements shall be made for urgent protective action to be taken promptly, in order to avert doses off the site in accordance with international standards.*

EPD (Extended planning distance): *within which instructions will be provided to reduce inadvertent ingestion, and dose rate monitoring of deposition conducted to locate hotspots.*

ICPD (Ingestion and commodities planning distance): *within which instructions will be provided to place grazing animals on protected feed, to protect drinking water supplies, to restrict consumption of wild-grown products, milk from grazing animals.*

Table 1. IAEA EPZ

Emergency zones and distances	Suggested max radius (km)	
	1000 MW(th)	100~1000 MW(th)
PAZ	3 to 5	
UPZ	15 to 30	
EPD	100	50
ICPD	300	100

2.4 Safety Goal

There are two cases where EPZ is related to safety goal policy [11]. One is Seabrook unit 1 EPZ case. In 1986, Massachusetts refused to involve in the emergency planning exercises for Seabrook unit 1 of New Hampshire, even though the EPZ of Seabrook includes the lands several miles inside of Massachusetts. Thus, Seabrook request 1 mile EPZ to avoid Massachusetts interference, and showed 1 mile EPZ satisfied the safety goal [11] which was just issued at that time.

The other case is the decommissioned plant such as Vermont Yankee plant. Even though the reactor was not used, it looks dangerous if PEPZ is reduced since spent fuels are remained inside of site boundary. However, the decommissioned plants showed the safety goal is still satisfied even though PEPZ is changed to the site boundary instead of 10 miles [12]. Thus, all decommissioned reactors are exempted from EPZ requirements or have site boundary PEPZ.

The safety goal is recently involved in the F-C curve suggested by the industry-led Licensing Modernization Project (LMP) where EPZ is scalable [13-14], and which is in detail mentioned in the next section.

2.5 EPZ for SMR

The backbone of EPZ criteria is NUREG-0396 [5] as mentioned in the section 2.2 EPZ History in USA. The NRC position papers [15-16] about scalable EPZ for SMR, and NEI report [17] for the reduced EPZ for SMR are all based on the criteria of NUREG-0396 [5].

A problem in using the criteria of NUREG-0396 for SMR EPZ was that the analyses with DBA and BDBA source terms simply presented dose-distance curves conditional upon the occurrence of the source term without consideration of frequency. However, in the recent draft guide [18] and meeting [19] of NRC, for severe accidents (BDBA), dose-distance results are aggregated using frequency information to evaluate the likelihood of exceeding particular dosimetric criteria as a function of distance, and scalable EPZ is admitted.

The EPZ of HTR-PM [20] may adopt the recent US NRC trend for SMR in which the scalable EPZ and the use of frequency for the severe accident scenarios are admitted. Thus, the PEPZ of HTR-PM was determined by site boundary whose radius is 500 meter [20].

The other approach for SMR EPZ is F-C curve approach [13] derived by the industry side, which is going to get an endorsement of NRC [14]. The F-C curve is shown in Fig. 1.

IAEA also studied EPZ for SMR, and the scalable EPZ, and the use of frequencies for accidents scenarios were discussed in 2009 [21].

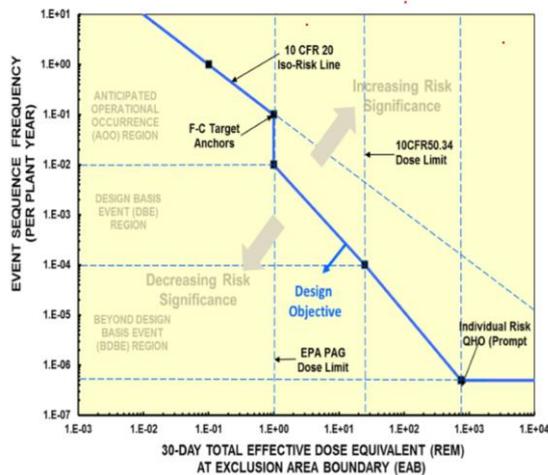


Fig 1. Frequency-Consequence Target

3. Results and Conclusions

The U.S. approach for EPZ is dose saving concept, and the criteria of NUREG-0396 [5] is still backbone which the future reactors such as SMR should satisfy. Although the criteria of NUREG-0396 will exist, the following two approaches will be realized in soon. One approach is the admitting of the scalable EPZ and the use of frequencies for accident scenarios by NRC. The other approach is F-C curve approach derived by the industry side, as a new LMP, which will be endorsed by NRC in soon. Concerning with EPZ of SMART reactor, it is easy to apply US NRC approach since the scalable EPZ and the use of frequencies for accidents scenarios are admitted. Similar to U.S. NRC approach for SMR EPZ, IAEA discussed the scalable EPZ and the use of frequencies for accidents scenarios. However, further discussion is required to make a policy

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