

A Study of Emergency Planning Zone (EPZ) Establishment for A Multi-Module SMR

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1. Introduction

In 2020, U.S. NRC issued a design certification (DC) for the NuScale small modular reactor (SMR) which has very short emergency planning zone (EPZ) less than 1 km, and multiple modules. After the DC, many people are interesting in the NuScale's determination of EPZ distance, especially in the case of the multiple module reactor.

This paper describes the U.S. regulatory requirement for the multiple module EPZ, and NuScale EPZ example. In addition, multiple module effect in the determination of EPZ distance is discussed.

2. Methods

2.1 U.S. EPZ Requirement for Multi-Module Reactor

The U.S NRC discussed the regulation for the multiple module SMR in 2011 [1]. However, since there are many different type SMRs, it is not easy to make an adequate regulation to fit for all SMRs. The current NRC's regulation is only the guidance in SRP Section 19.0 [2] which directs the staff to verify;

... the applicant has (1) used a systematic process to identify accident sequences, including significant human errors, that lead to multi-module core damages or large releases and described them in the application and (2) selected alternative features, operational strategies, and design options to prevent these sequences from occurring and demonstrated that these accident sequences are not significant contributors to risk.

However, there is no special EPZ requirement for the multi-module SMR in U.S.

2.2 NuScale Multi-Module EPZ Example

NuScale SMR which has 12 modules in a reactor. "Multi-Module (MM) CDF Factor" and "MM-LERF Factor" are defined [3] as;

Results are presented in terms of a bounding estimate on the conditional probability that multiple modules would experience core damage (or large release) following core damage (or large release) in a single module.

MM-CDF factor is 0.13, and MM-LERF factor is 0.01 in NuScale SMR [3]. With these MM-CDF factor and MM-LERF factor, we can understand that the multi-module risk of NuScale SMR is small although there exit 12 modules. If a multi-module accident sequence frequency is less than 10^{-7} , then it can be neglected in the determination process of EPZ [4-5]. The mean value of the MM-CDF due to internal events for multiple modules was calculated to be $4.1E-11$ per mcyr [3], that is, on the order of ten percent of the CDF calculated for a single module. Thus, the multi-module accident sequences would be neglected in the determination process of EPZ.

2.3 Multi-Module Effect in Determination of EPZ

As we can see in the NuScale MM-CDF factor, it is not risky as much as 12 times when there are 12 modules. It is 10% more risky, and which is still belong to negligible. The reason to get the high quality safety in the multi-module reactor is due to the design accordance with 10 CFR 50 Appendix A GDCs 2, 4, and 5, which require 1) module separation, 2) design against CCF, ... etc. According to SECY-16-0012 [6],

... the siting of a multi-module plant, including the determination of the EAB, LPZ and population center distances, is currently expected to be based upon the evaluation of a single reactor.

Thus, if MM-CDF factor is small enough, the EPZ determination can be done based on the evaluation of a single module.

2.4 Multi-Module Example for 1,000 MW

Let's assume that A and B SMR has 10 modules of 100 MW and 4 modules of 250 MW, respectively, as a

1,000 MW SMR. Which SMR could have a shorter EPZ distance? Since it would be possible that EPZ distance is derived based on the evaluation of single module, 10 modules SMR has the shorter EPZ distance. Because source terms which are released to offsite depend on single module capacity.

When the number of module change from single (e.g. 1 MW) to 10 (e.g. 1 x 10 MW) in a SMR, the amount of offsite dose resulted from an accident does not increase as much as 10 times. Rather, the offsite dose in an accident is almost the same. However, the accident occurs 10 times as often as before in the 10 modules SMR.

In Fig. 1, the EPZ distances derived by the criterion c (i.e., the distance where the probability of exceeding 200 rem whole body acute dose falls rapidly below $1E-3$) [7] are shown according to the number of modules when we assume that there occur simultaneously a severe accident among the multiple modules. In Fig. 1, the EPZ distances vary in the direct proportional to the number of modules even though the proportional ratio is less than 1. In the real world, since the simultaneous accidents among multiple modules do not occur (i.e. negligible), the EPZ of the multiple modules is almost the same one of single module.

For the previous A and B SMR case, by the assumption that an accident occurs simultaneously in the all modules if a multiple module accident would occur (i.e. 10 module simultaneous accident for A SMR, and 4 module simultaneous accident for B SMR), the distances derived by the criterion c would be the same by the assumption that the total released source terms are the same.

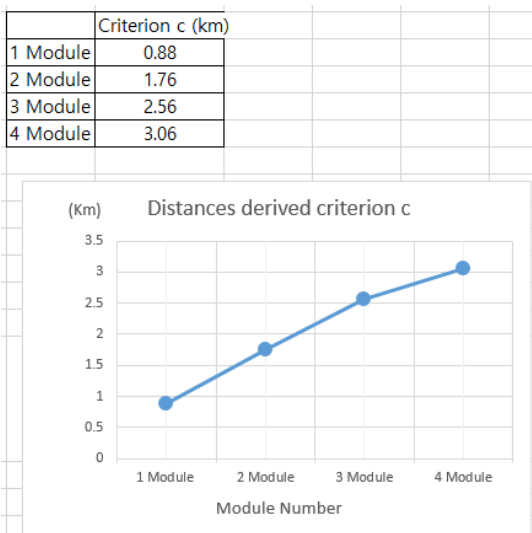


Fig. 1 Criterion c distances depending on the number of modules by assuming simultaneous multiple module severe accident

3. Conclusions

Since the multi-module SMRs are designed more carefully to escape from the multiple events, it is possible to use the EPZ derived based on a single module for the multi-module SMRs. Thus, for the same capacity reactor (e.g., 1000 MW), the more module SMR (e.g., 10 modules of 100 MW) has shorter EPZ distance than the less module SMR (e.g., 4 modules of 250 MW).

Acknowledgement

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