A Review on the Safety Goal for Multi-Units of Nuclear Power Plants

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1. Introduction

In Korea, the public acceptance for nuclear power plants (NPPs) is not good after Fukushima accident. Especially, since multi-units more than 4 units locate a site in Korea, many people including the anti-nuclear group argue that a new regulation about multi-units should be set up and are waiting for the results of multi-units risk research.

First of all, we review the history of the safety goal related to the multi-units in USA and in Korea. Then, whether the requirement of Cs-137 release into environment is related to multi-units is also reviewed.

2. Methods

2.1 Safety goal for multi-units in USA

As mentioned in Ref. [1], about 90 ideas and models for safety goal were suggested during 10 years before the safety goal was finally set up in 1986 in USA. At that time, many ideas and models were related to multi-units, i.e., site risk.

The 1st preliminary policy statement for safety goal was issued 1982 [2]. In that policy, the safety goal was based on the multi-units as shown in the following excerpt [2].

> *"The risk to an individual or to the population in the vicinity of a nuclear power **plant site** of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed."*
>
> *"The risk to an individual or to the population in the area near a nuclear power **plant site** of cancer fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1%) of the sum of cancer fatality risks resulting from all other causes."*

After reflecting comments during 1982, the 2nd preliminary policy statement for safety goal was issued 1983 [3]. In that policy, the safety goal was based on single unit as shown in the following excerpt [3].

> *"The risk to an average individual in the vicinity of a nuclear power **plant** of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed."*
>
> *"The risk to the population in the area near a nuclear power **plant** of cancer fatalities that might result from nuclear power plant operation should not exceed one-tenth of one percent (0.1%) of the sum of cancer fatality risks resulting from all other causes."*

The reason why NRC changed the safety goal from 'per site' to 'per unit' was shown in the below excerpt [3].

> "*Some commenters objected to the originally proposed individual and societal numerical guidelines because they were to be applied on a per-site basis. This would have resulted in tighter requirements being imposed on plants at multi-unit sites than at single-unit sites. The Commission decided not to impose a regulatory bias against multi-unit sites. Therefore, the quantitative design objectives were changed from risks per site to risks per plant. "*

Eventually, the final policy statement for safety goal was legislated based on the single unit basis [4].

In 2005, the multi-units safety goal was discussed again in USA [5]. Because advanced nuclear reactors, next generation reactors, or small modular reactors have very different core melting mechanism, and/or multi-modules like multi-units. Thus, a technology neutral regulatory framework was developed [5]. And, NRC staff suggested that the safety goal legislated in 1986 [4] could be used for the multi-units or multi-modules as shown in the below excerpt [5].

> *However, in applying the Quantitative Health Objectives(QHOs), the policy statement for the "Safety Goals for the Operation of Nuclear*

Power Plants" refers to "The risk to an average individual in the ***vicinity of a nuclear power plant…*** *" and "The risk to the population in the* ***area near a nuclear power plant*** *…". Hence the safety goal policy could be interpreted to mean that the risk should be calculated on a per site basis. This also has implications for the level of safety for new plant licensing.*

In 2007, we can see that the above NRC position for multi-units safety goal was not changed as cited from Ref. [6].

Traditionally, plant risk information has been calculated and used on an individual reactor basis, regardless of the number of reactors on a given site. However, with the possibility of future reactors being of a modular nature (i.e., several small reactors co-located to produce the power output of one large reactor) and with the potential for future reactors to be put on existing sites which already contain one or more reactors, the need to consider the integrated (i.e., cumulative) risk from all reactors on a site has been raised.
…
require that the integrated risk from all future reactors on a site be used in assessing whether or not the risk criteria proposed in the Framework (e.g., QHOs) are met (the risk from existing reactors on a site would not have to be considered).

2.2 Safety goal for multi-units in Korea

The safety goal in Korea [7] is very similar to that of USA [4] issued in 1986. The safety goal based on the multi-units was not officially announced in Korea. However, it is being studied.

2.3 Safety goal for multi-units in the other country

In U.K., the safety goals are based on site [8]. The safety goal of U.K. was developed by ALARP (as low as reasonably practicable) concept, and an example of safety goal of U.K. is shown in Table 1 [9]. From the beginning of safety goal development, site based safety goal models were suggested in U.K. For example, Kinchin [10] suggested that each of an assumed population of 100 reactors in the U.K, was assigned 1/100 of the total risk [11].

South Africa's safety goal is also site basis as shown in Table 2 [8].

The safety goals of Japan, Canada, and Finland are based on single unit [8]. An example of Japan's safety goal can be quoted from Ref. [8] as below;

Table 1. An Example of Safety Goal in U.K.

Target	**BSO***	**BSL****
Individual risk of death to a person on site, from accidents at the site resulting in exposure to ionising radiation	1 in a million per annum	1 in 10 thousand per annum
Individual risk of death to a person off the site, from accidents at the site resulting in exposure to ionising radiation	1 in a million per annum	1 in 10 thousand per annum
Total risk of 100 or more fatalities, either immediate or eventual, from accidents at the site resulting in exposure to ionising radiation	1 in 10 million per annum	1 in 100 thousand per annum

*BSO : Basic Safety Objective
**BSL : Basic Safety Level

Table 2. An Example of Safety Goal in South Africa

Public	Accident
Average Annual Population Risk	1E-8 fatalities per person per year per site

The mean value of acute fatality risk by radiation exposure resultant from an accident of a nuclear installation to individuals of the public, …, should not exceed the probability of about 1E-6 per year. And the mean value of fatality risk by cancer caused by radiation exposure resulting from an accident of a nuclear installation of individuals of the public, …, should not exceed the probability of approximately 1E-6 per year.

2.4 Requirement of Cs-137 Release Into Environment

Finland is the first country asking the requirement of Cs-137 release into environment. That is,

".. mean value of a large radioactive release frequency (more that 100 TBq Cs-137), as estimated from a comprehensive level 2 PRA, is less than 5.0E-7/yr" [8]

Since the safety goal of Finland is single unit basis, the requirement of Cs-137 release is based on single unit [12].

As mentioned in Ref. [13], the Cs-137 release requirement is necessary for the approval of each reactor design, and which seems to be related to single unit basis. However, after Fukushima accident, the

offsite property damage and land contamination became an important factor to be controlled [14]. Thus, the Cs-137 release criteria could be used for the safety goal related to the factor. In this point of view, we could think the Cs-137 release criteria are related to site basis.

3. Results and Conclusions

We reviewed the papers and reports which deal the safety goal for NPP multi-units. Since "100 TBq Cs-137 release into environment" is a reactor design criteria, it could be single unit basis. However, since its purpose is to prevent the contamination, it could be also multi-units basis. Further research is required on this issue.

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