Safety Goal, Multi-unit Risk and PSA Uncertainty

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1. Introduction

After the Fukushima accident, many countries are revisiting the safety goal for nuclear facilities including nuclear power plants (NPPs). Some countries like the U.S.A. operate the regulation system based on the safety goal for NPPs. The safety goal is an answer of each country to the question "How safe is safe enough?" [1]. Table 1 shows some examples of the safety goal [2].

Table I: Some examples of the Safety Goal

Definition	Regulation	Country, Ogr.
Limit individual latent cancer risks < 0.1% of general cancer risk	LERF	USA
Limit frequency of occurrences of Population fatality	Frequency of population fatality	UK, Holland
Limit amount of radioactivity release of specific nuclide (Cs) . To fulfill the requirement, frequency of the release is limited	Frequency to limit Cs release	Holland, Finland
Limit radioactive release by a fraction of core inventory. Limit frequency to limit release	Limit frequency of radioactivity release	Sweden
Limit off-site emergency activities	Emergency response	IAEA

However, many countries including Korea do not have the official safety goal for NPPs up to now since the establishment of safety goal is not just a technical issue but a very complex socio-technical issue. In establishing the safety goal for nuclear facilities, we have to consider various factors including not only technical aspects but also social, cultural ones.

Recently, Korea is trying to establish the official safety goal [3]. In this paper, we will review the relationship between the safety goal and Probabilistic Safety Assessment (PSA). We will also address some important technical issues to be considered in establishing the safety goal for NPPs from PSA point of view, i.e. a multi-unit risk issue and the uncertainty of PSA.

2. Issues related to the Safety Goal

2.1 Safety Goal in Korea

Before we review the relationship between the safety goal and PSA, it would be better to think about the necessity of the safety goal in Korea at first.

Recently, Korean nuclear industry lost the credibility on the safety of NPPs from the public due to various factors such as the station black out event at the Kori unit 1 and the falsely-certified parts issues in addition to the Fukushima accident. Korean nuclear society had to use a lot of resources to resolve these issues.

Even though, the crimes related to these issues should be punished, the impact of such issues on the safety of Korean NPPs is another problem. If we have the official safety goal agreed from the public, the decision making process to resolve these issues would be proceeded based on the scientific background and we can save a lot of resources which can be used for real safety improvements of NPPs.

In addition, we are also building new NPPs at the same and/or very near site. This can cause some problems in the public acceptance nearby a site. We should establish a philosophical basis on the safety to ensure the safety of the public. The safety goal will be one of the important bases. So we think that nowadays is the time to establish the Korean safety goal. As mentioned previously, the safety goal is to be determined considering social aspects, however in this paper, we will focus on technical aspects.

2.2 Safety Goal and PSA

Usually, the safety goal for the NPPs has a hierarchy structure: qualitative goals of a higher level, and quantitative goals of a lower level. The expressions used to describe the safety goal such as "insignificant risk" of the US NRC and/or the "practically eliminate" of the IAEA are examples of the qualitative safety goal [4, 5]. The qualitative goal is a good tool to communicate with the public. In some cases, only the qualitative safety goal is defined such as in the case of Western European Nuclear Regulators' Association [3].

However, without the quantitative safety goals, we cannot say whether the current status of a NPP satisfies the qualitative safety goals or not due to the intrinsic nature of the qualitative safety goal. So we need additional quantitative surrogates such as the target value of CDF (Core Damage Frequency) and/or LERF (Large Early Release Frequency) [4].

The NRC has used PSA as a tool to check whether the safety goal of a NPP is satisfied or not. Even though, some countries have the quantitative safety goals with different forms from those of the U.S.A., they also use PSA as an important tool to check the safety goal. In using PSA for checking the quantitative safety goal, there are two important issues. The first one is a multi-unit risk issue and the second one is the uncertainty of PSA.

The first one is related to the definition of the safety goal. However the second one is an intrinsic issue in PSA. In next sections, we will review these issues.

2.3 Multi-unit Risk

Even though some countries such as the U.S.A. have the concern on the multi-unit risk before the Fukushima accident, the Fukushima accident revealed the importance of the multi-unit issues again. Many countries have interest in this issue after the Fukushima accident. Especially, we have to pay attention to this issue since we have from 4 to 8 units in a site.

When the NRC tried to define the safety goal in mid of '80, there were discussions on the scope of the safety goal. At that time, the NRC determined that the safety goal is per-reactor based since they thought that the risk from multi-unit accident is negligible. Even after the Fukushima accident, the NRC assumes that the multi-unit risk is not a big problem [6].

In the U.S.A., the maximum number of units is 3 and they also have a very important barrier that Kora does not have, i.e. the distance between NPPs and nearby cities. However, in Korea, we think that the multi-unit risk would not be negligible since we have many units in a site and sites are located nearby big cities with huge populations.

The IAEA's definition on the safety goal seems logically sound that requires stricter targets for new NPPs considering the increasing numbers of NPPs [5]. However, it is difficult for people nearby old NPPS to accept the IAEA approach especially in Korea.

We think that the Korean safety goal should include the multi-unit aspects. In addition, the safety goal considering the multi-unit risk might have a positive impact in communicating with the public when we try to build additional NPPs at an existing site.

2.4 PSA and its uncertainty

In many countries, PSA is used as a tool to confirm the safety goal [1] since PSA is the only way to show the "integrated" safety of a NPP.

If we establish a Korean safety goal, then the regulator should define the role of PSA with respect to the safety goal. In other words, the role of PSA should be defined in the regulation framework. It will be a very difficult task. We think only the U.S.A. and U.K. have the regulation frameworks that clearly define the relationship between the safety goal and PSA. For instance, the Risk-informed Regulation (RIR) of the U.S.A. defines the relationship between the safety goal and PSA clearly. RG 1.174 of the NRC is a base document for the RIR that.174 defines the relationship between PSA and the safety goal. In addition, it defines the role of PSA in the current regulation framework, i.e. it describes the relationship between PSA and the deterministic safety principals such as the defense-in-depth and safety margin [7].

However, many countries have some problems in incorporating PSA into the deterministic regulation framework. It seems one of the main causes of such problems is the concerns about the uncertainty of PSA. Even some nuclear experts insisted that the results of PSA could not be used for the regulation due to the uncertainty of the results.

However, in many cases, we think that such concerns arose from the misunderstanding on PSA. PSA is developed basically to handle the uncertain situations. For instance, one of the main objectives of PSA is to estimate the likelihood of unanticipated accident scenarios that cannot be estimated by the deterministic approach. That is the reason why we use the probability in PSA, especially Bayesian probability [8].

It is well known that the uncertainty of PSA can be classified into two categories: aleatory and epistemic uncertainty [9]. The main uncertainty sources of each PSA level are shown below:

- Level 1 PSA: the randomness of structure, system and component
- Level 2 PSA: the severe accident phenomena
- Level 3 PSA: the limitation of knowledge on dispersion, the effect of low dose, etc.

PSA is the only way to handle the aleatory uncertainty. However, the epistemic uncertainty is not only the problem of PSA but also ones in many deterministic areas of nuclear engineering. Such uncertainty comes into PSA when we used the results of many deterministic areas such as the deterministic safety analysis including the severe accident, etc.

Such uncertainty is not disappeared even though we are not using such knowledge in PSA, and it might cause some problems in daily operation of NPPs. For instance, some structure, systems and components will fail randomly. Such randomness should be covered in the regulation. If we want to make the best regulatory and/or operational decisions, we have to use all knowledge that we have including the uncertainty.

In other words, the uncertainty is not the weak point of PSA but the intrinsic nature of PSA. We don't need to worry about the uncertainty but have to understand it. For instance, the completeness issues cannot be resolved even though we expand the scope of PSA and the technology level of PSA continuously. The goal of PSA is not to eliminate the uncertainty but to understand it.

3. Conclusions

In this paper, we reviewed some issues related to the safety goal and PSA. We believe that the safety goal is to be established in Korea considering the multi-unit risk.

In addition, the relationship between the safety goal and PSA should be also defined clearly since PSA is the only way to answer to the question "How safe is safe enough?" In addition, the role of PSA in the regulation framework should be defined as well i.e. the risk-informed decision making process is to be a part of the regulation framework.

However, we also need to aware the limitations of PSA well. That is the only way to make appropriate risk-informed decision makings. The best decision making process that we have until now for the nuclear safety issues.

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