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Small Numbers and Use of PSA

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1. Introduction

PSA is defined as a mathematical methodology development and application. It is not perfect because it depends on many incomplete factors such as assumptions, theories, hypotheses, scope, information handling limitations, and analysts.

However it is the best method avaiable nowadays. Until a better methodology comes out, we are often advised to use PSA to make the best decisions in assessing and managing the risk of nuclear power plants[1)].

PSA people need to pay sincere attention to the quality of PSA including those factors described above in order for us to use PSA as important input to our risk assessment and management.

2. Small Numbrs

An issue I had struggled to answer people even nuclear engineers why the Fukusima Daiichi accident happened, though the annual frequency of a core damage event is evaluated to be a value of about $1x10^{-5}$/RY.

Over 30 years in my PSA career I have meditated the meaning of the small numbers. It has been routine that the CDF or LERF is calculated to be very small numbers. It is a challenge to PSA people to develop and maintain an understanding of the small numbers. They are not statistical and objective value but a degree of belief or subjective value basically.

It is important to appreciate the meaning of small numbers because we can be in danger of developing models with the small numbers by overlooking fundamental weakness in our reasoning. For instance, if we conclude that the unavailablity of a WS1 ECCS system is 10^{-4}, we are saying that that ECCS system would be not available to perform its function – for any reason including system failure, maintenance of all types or testing – for a period less than an hour in a year. This system is really a very well designed.

If we were to conclude the mean annual frequency of a core damage event for the SMART plant is 10^{-7}, then we are saying that if we had a population of 10 million similar plants on similar sites, we would expect to observe one core damage event per year. 10^{-7} is indeed a very small number.

So how should we react if we were to be told that the annual mean core damage frequency from all initiators for a plant is 10^{-9}? I expect they may react with disbelief. Such a frequency would imply a core damage event at this plant would be expected once in a billion years. Are such values believable? It is always a big challenge to answer the meaning of the small numbers PSA people produce.

3. Use of PSA

Last June 2015 the adoption of PSA in FSAR and the prepartion of the accident management progrms are included by the nuclear safety laws associated with the operting licensing of the nuclear power plants to be constructed in future in Korea.

In USA from the Kennedy Report on the TMI-2 accident to the updated version of the Reactor Safety Study, namely NUREG-1150[2,3)], there had been encourgement from the NRC of research to increase the use of PSA in its licensing activities. For more than two decades unlike Korea, the NRC has been promoting the concept of a risk-informed regulation.

I guess no one might disagree with a cautious approach to transtioning to a licensing process where quantitative methods of risk assessment play a important role. But many nuclear experts think that transition has been unnecessarily slow because the burden on the licensee has been to satisfy both traditional deterministic licensing requirements and those having to do with risk-informed practices.

Now in US, under 10 CFR Part 52, new nuclear power plants are required to have a Level 1 and Level 2 PSA and to maintain and upgrade the PSA according to requirements specified by the regulation. For the existing nuclear power plants, the individual plant examinations to identify the plant specific vulnerabilities have been performed voluntarily.

PSA is like a microscope for determining what can go wrong in a complex system. It provides new perspectives on safety and deepen the understanding of risk beyond design basis considerations. The ability to quantify the rank order of possible accident sequences and contribution to risk on the nuclear power plant is one of important PSA achivements.

The PSA which is getting more widely used in regulation and industry is however not perfect. There are many uncertainty such as model, parameter, analyst, and incomplete uncetainties in the results of the PSA. The uncertainties are derived from the theories, assumptions, hypothesis, and modeler capability. How do we understand the small numbers shown in risk? What is the truth of the plant risk? What is risk perception people feel? Nowadays risk perception is important conversation topic.

The perception of risk is linked to the concept of "acceptable risk," that is the question of what risks are considered to be tolerable. Part of this understading is influenced by past experience. We have made decisions in the past based on incomplete knowledge with unexpected negative outcomes. Often we did not realize our knowledge was critically incomplete. We tend to remember and weigh such tragic examples at the expense of more benign or even positive outcomes. The Baysian interpretaion for the small numbers and relevant arguments will be introduced in this presentations.

3. Remarks

PSA is not perfect because it depends on many incomplete factors such as assumptions, theories, hypotheses, scope, information handling limitations, and analysts. However it is the best method avaiable nowadays until a better methodology comes out. Now it appears that the USNRC and NRA in Japan are exhibiting more interests in upgrading the use of PSA than before.

PSA people need to understand the risk and relevant information which is important for regulators and the utility to fulfill their mission of assuring reactor safety.

We need to prepare risk information; "What can happen in the system?" "How likely is it to happen?" and "What are its consequences, given that it occurs?" Because it is not possible to test all conditions for the system to answer these questions. We also need to study in depth to answer these questions in the form of risk curves including uncertainty in frequencies, comprehensively treating model and parametric uncertainties and executing sensible sensitivity studies.

By understanding the capability advantages and the meaning of small numbers in PSA, the utilization of PSA needs to be expanded especially for regulators' decision-making framework. Also we need to pay sincere attention to the quality of PSA in order to make the best decisions in assessing and managing the risk of nuclear power plants

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[3] U.S. Nuclear Reguatory Commission, Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, NUREG-1150, 1990.