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The Role of Level-3 PSA in the Regulatory Structure for the Licensing of Future NPPs

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1. Introduction

The probabilistic safety assessment (PSA) provides a systematic analysis to identify and quantify all risks that the plant imposed to the operators, general public and the environment and thus demonstrates compliance to regulatory risk criteria. Therefore, the PSA has been being played an important role in the development of safety requirements for the existing plants, mainly reactors using light water technology. However, the existing safety requirements may not be fully applicable to the future reactors due to the advances in technology, new safety options, and new strategies for managing abnormal plant conditions. Therefore, a comprehensive set of technology-neutral safety requirements are being developed by the IAEA[1] and USNRC[2].

Especially, USNRC is developing a basis for a regulatory structure that is applicable to all types of reactor designs, including gas-cooled, liquid metal, and heavy and light water-moderated reactors because metrics such as core damage and large early release may not be applicable to some advanced reactor designs. They are developing this kind of basis for a regulatory structure in order to provide a technology neutral safety approach that will guide the design, construction and operation, as well as safety assessment, of innovative reactors.

They are using the quantitative safety goals expressed by means of a frequency-consequence diagram. Within this approach, the scope of the PSA needs to encompass a whole spectrum of off-normal events including frequent, infrequent, and rare initiating events and event sequences. These events include a spectrum of releases from minor to major, and sequences that address conditions less than the core damage sequences. It also needs to address the dose consequences of these event sequences as measured at the exclusion area boundary (EAB). In order to obtain dose consequences for the whole spectrum of off-normal events, the dose evaluation by using the deterministic and probabilistic approaches has to be accomplished. Therefore, the role of Level-3 PSA for the evaluation of dose consequences will be examined in this study.

2. The Role of Level-3 PSA

The foundation of the new safety approach for future NPPs proposed by the IAEA are shown in Figure 1 which outlines the elements that make up the safety philosophy, these are: safety objective, safety goal, safety functions, and defense-in-depth. A safety goal for the design is identified in terms of allowable consequences for a given event; it is derived from the Safety Objectives and expressed in quantitative terms. The approach for assuring the safety of a nuclear power plant follows the principal that plant states that could result in significant but still allowable radiation doses or radioactive releases are of very low frequency of occurrence, and plant states with significant frequency of occurrence have only or no potential radiological consequences.

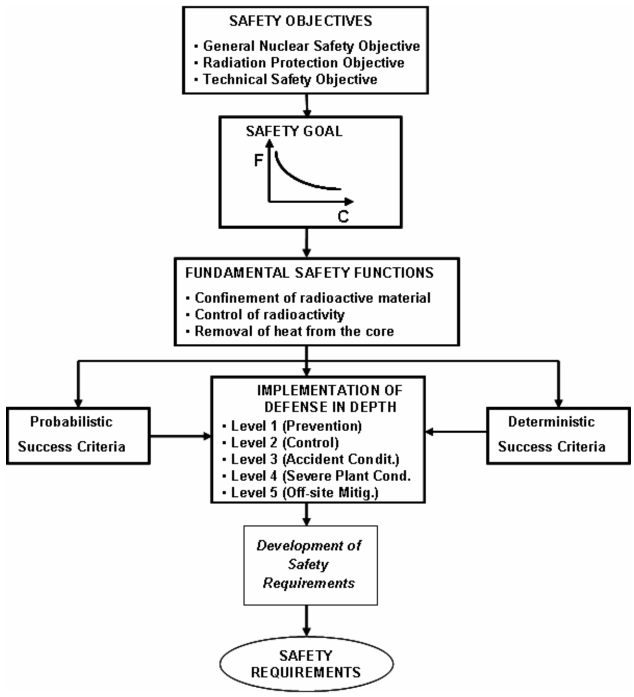

Fig. 1. Safety philosophy incorporating new safety approach.

Figure 2 shows a frequency versus consequences curve that separates the acceptable and unacceptable regions of frequencies and consequences. The event frequencies can represent events that occur during the normal and abnormal operation of a nuclear power plant and the consequences can refer to public health and safety. This curve can be used as an illustrative schematic representation of the desired level of the nuclear plant and here is referred to as the Safety Goal. The quantitative Safety Goals are used to define the level of acceptability, with allowances for uncertainties.

Therefore, we have to obtain the exposure doses for the whole spectrum of off-normal events. Especially, the events with low frequency, high consequences with potential significant health effects on the population in the vicinity of the plant, and major environmental impact, referred to as the residual risk from a plant. The exposure doses can be evaluated for the whole spectrum of off-normal events by using the Level-3 PSA. Level-3 PSA is defined as a set of realistic calculations of the ranges (probabilities of occurrence and magnitudes) of adverse impacts that would follow from an accidental release of radionuclides. These adverse impacts, commonly referrer to as "public risks," include (1) early and long-term deaths; (2) early and long-term injuries; (3) genetic damage; (4) the contamination of property, land, and water; (5) economic impacts[3]. The general procedure of the Level-3 PSA is shown in Figure 3.

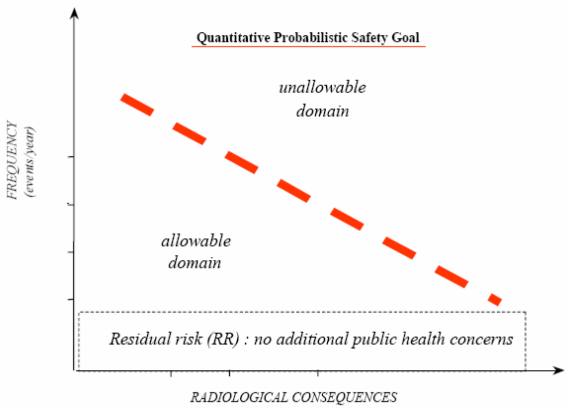

Fig. 2. Frequency vs. consequence safety goal.

Also, the USNRC is continuing its State-of-the-Art Reactor Consequence Analysis (SOARCA), which will be used to realistically predict the consequences of potential accidents at commercial U.S. reactors. They found that there are problems associated with the use of CDF as a numerical screening criterion to restrict the scope of subsequent Level-2 and Level-3 analyses. In such PSAs, the most important contributors to offsite consequences are not necessarily significant contributors to CDF, and are not necessarily characterized by initial containment bypass events. The number of these sequences and their aggregate contribution to overall plant risk can increase dramatically as the numerical cutoff is reduced. Thus, application of a priori CDF screening criteria can inappropriately overlook many risk-significant scenarios. Such an approach also does not provide a fully integrated evaluation of risk in terms of frequency and consequences. Therefore, we have to perform a Level-3 PSA for virtually all sequences.

3. Concluding Remarks

The Level-3 PSA can be a very important tool for the support of a development of a comprehensive set of technology-neutral safety requirements for future reactors. Also, we may identify suitable Level-1 event screening criteria and simplifying assumptions that could be used to develop a defensible, simplified approach by the results of a full set of consequence analyses of a power plant.

Acknowledgement

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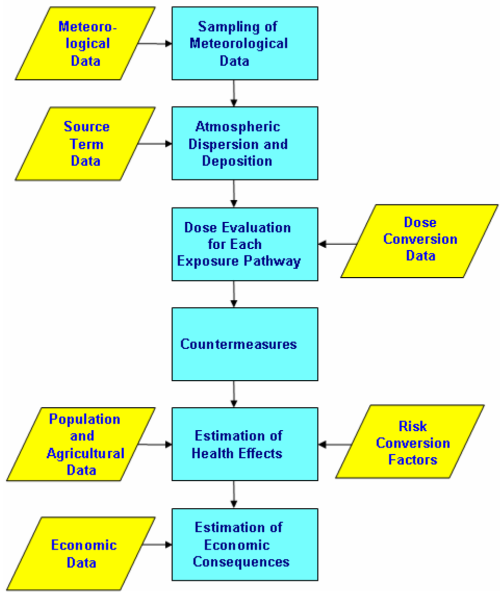

Fig. 3. The general procedure of the Level-3 PSA

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