*Transactions of the Korean Nuclear Society Autumn Meeting*
*PyeongChang, Korea, October 30-31, 2008*

# Survey on Probabilistic Elements among Potential Safety Requirements of TNF

Kju-Myeng Oh*, Sang-Kyu Ahn, Hun-Joo Lee, Chang-Ju, Lee
*Korea Institute of Nuclear Safety, Gusung-dong Yusung-gu Daejeon, Korea, 305-338*
**Corresponding author:* k313okm@kins.re.kr

## 1. Introduction

Several countries inclusive of Korea have actively carried out the research and development on new conceptual, innovative plants like Gen. IV reactors which are substantially different from existing LWRs in view of their unique design concept and safety characteristic.

These countries have proposed and developed or have a plan to adopt regulatory technology-neutral framework (TNF) which can be applied regardless of their reactor types in order to enhance the effectiveness, efficiency, and predictability of future plant licensing.

Especially, NRC has provided the approach that appropriately integrates deterministic and probabilistic elements in the development of technical requirements for future reactor. This approach includes more extensive use of risk-informed, performance-based approach. Accordingly, this study focused on probabilistic elements amidst potential safety requirements of RIPBR described in NRC' TNF and IAEA' TNF.

## 2. Approach to development of safety requirement of RIPBR in NRC's TNF and other guidelines

### 2.1 Integrated process for safety requirement

The safety fundamentals ensure protection of the public health and safety, and accomplish the safety, security and preparedness goals and expectations as shown in Fig. 1. The safety fundamentals are defined in terms of five protective strategies (Physical protection, stable operation, protective systems, barrier integrity, and protective actions). A logic tree is developed for each protective strategy that identifies the failure cause of the protective strategy as shown Fig. 2.

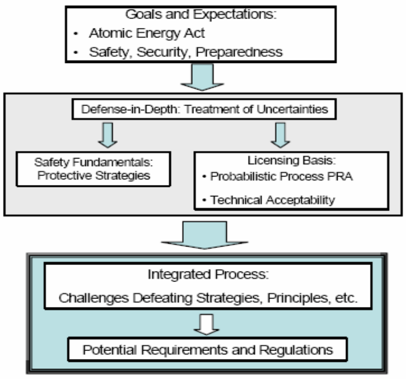


Fig. 1 Framework integrated process

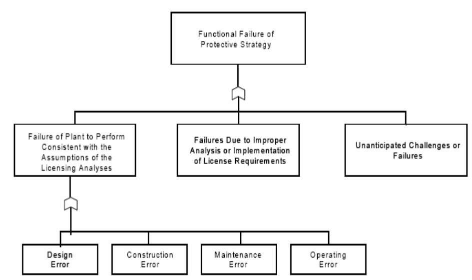


Fig. 2 Example logic tree

The defense-in-depth principle is then applied to each protective strategy and licensing basis (probabilistic process of PSA and technical acceptability). Defense-in-depth measures are identified, which should be incorporated into the requirements to help prevent protective strategy failure.

The answers to the questions for each protective strategy lead to the identification of specific topics that the requirements will need to address to ensure adequate implementation of the protective strategies.

### 2.2 Development of safety requirement

Through integrated process for safety requirement, the topics for which requirements are needed are organized by design, construction, operation, their common topics, physical protection, and administration.

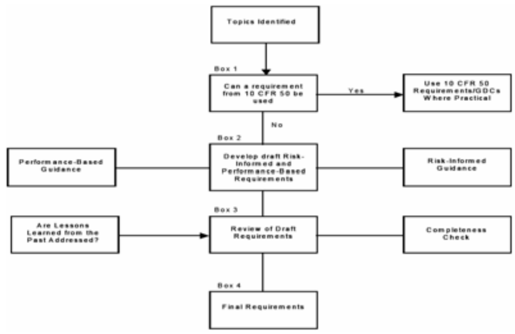


Fig. 3 Development of requirements

The development process of safety requirements is delineated in Fig. 3. The general design criteria (GDC) contained in 10 CFR 50, Appendix A. serve as a good example in developing technical requirement of TNF. It may possible to properly use some of the existing GDCs requirements. In other cases, more specificity may be needed in some requirements where specific criteria of design features are considered if necessary. That is, some modifications to existing requirements should be taken. In addition, new requirements may be necessary to address the various types of reactor technologies and to implement a risk-informed and performance-based approach.

### 2.3 Other guidelines

The method described in IAEA technical document and GIF document of the Objective Provisions Tree as shown in Fig. 4 is a systematic "critical review" of the implementation of the Defense in Depth. These provisions can then be grouped into the lines of protection (LOP) required to achieve each level of defense. The development of this tree provides the objectives for TNF; the guidelines to consider for the missions that must be achieved; and identification of the acceptable provisions (i.e. the design options) available to the designer and the required technical design specifications. The PSA results will be used to determine if the LOPs have the required reliability to satisfy the frequency goals and associated consequences for the level of defense being examined.

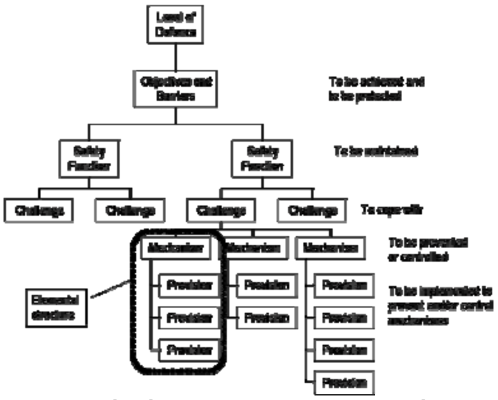


Fig. 4 The objective provisions tree approach

## 3. Survey on probabilistic elements of RIPB guidance

### 3.1 Probabilistic elements of RIPB guidance proposed by NUREG-1860

The topics for which requirements are needed in view of probabilistic elements of RIPB guidance are described in detail in NUREG-1860[1]. The topics are categorized into 3 parts as follows.

1) General topics common to design, construction, and operation
   - PSA scope and technical acceptability
   - Use of risk information
2) Good design practices
   - Plant risk:
     - Frequency-consequence
     - Quantitative health objectives (integrated risk)
   - Criteria for selection of LBEs
   - LBE acceptance criteria:
     - Frequent events (dose, plant damage), infrequent events (dose, plant damage), and rare events (dose)
   - Initiating event severity (potential to defeat two or more protective strategies < $10^{-7}$/ plant year)
   - Criteria for safety classification and special treatment
   - Reliability and availability goals consistent with PSA
     - Establish Reliability Assurance Program (RAP)
     - Specify goals on initiating event frequency
3) Good operating practices
   - Maintenance program & Maintenance of the PSA

### 3.2 Probabilistic elements of RIPB guidance proposed by other guidelines

The probabilistic elements described in IAEA technical document, GIF document, and RD-337 are solely quantitative safety goals including frequency of events-consequence, but do not provide definite dose criteria according to the frequency of event occurrence[2, 3, 4].

## 4. Discussion on probabilistic elements of RIPB guidance

Approach to NRC's TNF is similar to that of other TNF proposed by IAEA and GIF. In particular, they recommended the use of F-C curve or criteria in view of TNF for diverse future reactors which its depth and criteria itself, and the extent of its utilization are quite different. The F-C criteria proposed by NRC's TNF are more clearly specified than those of other TNFs proposed by IAEA and GIF. The level of PSA needed depends on the consequence metrics chosen for the safety goal representation. If the metrics are health effects, it is necessary to perform a Level 3 as well as a Level 1 and 2 PSA. If other metrics are available for a particular reactor concept, which can be used as surrogates for the health effects, it may need a Level 2 PSA analysis. In the case of NRC's TNF, the frequency-consequence curve is not a substitute for the QHOs, which express goals for the cumulative latent and early fatality risk from accidents. If generic site is used for compliance with regulatory limits, a level 3 PSA would still be needed for actual site. Actually, more extensive use of PSA was included in NRC' TNF as described in Sec. 3.1. In the case of IAEA's TNF, risk dominant accident sequences can be used to establish the necessary safety grade and reliability requirements of key SSCs. In more complicated manners, NRC's TNF proposed the LBE selection process and LBE criteria. The selection of LBEs based on event sequences from the PSA serves as a replacement for the traditional "single failure criterion" applied in the current licensing process. Each LBE selected from the PSA sequences must meet probabilistic criteria and additional deterministic criteria. However, these criteria include quantitative value not fully resolved as follows.

- Selection of cut-off frequency for event classes as 95$^{th}$ percentile frequency greater than $10^{-7}$/yr
- The frequency of an event class determined by setting the LBE's mean frequency to its 95$^{th}$ percentile frequency to the highest 95$^{th}$ percentile frequency of the event sequences in the event class.
- Use of the 95% probability value of the amount of radio-nuclides released for Source term calculations

For example, the pre-application case of SFR includes the residual risk having frequency less than $10^{-7}$/yr (different to cut-off frequency proposed by NUREG-1860) in F-C analysis. The SSCs credited in compliance with the LBE criteria are considered as risk-significant and special treatment is required. For this, it is necessary to establish the process so as to measure SSCs risk importance based on the F-C curve.

## 5. Conclusions and further study

Probabilistic elements among safety requirements of RIPBR in technology-neutral frameworks (TNFs) proposed by NRC, IAEA and GIF for future reactor licensing are surveyed, compared, and summarized as follows.

1) Frequency-consequence (F-C) curve or criteria should be properly established.
2) The LBE selection process and LBE criteria proposed by NRC's TNF still need to be confirmed for the applicability of specific future reactor such as VHTR, SFR, SCWR, etc potential to be deployed.
3) The detailed guidance for measuring SSCs risk importance and technical acceptability of PSA needs to be supplemented for extending utilization of F-C curve.

As a further study, it would need to appropriately develop the above probabilistic elements in developing safety requirement of RIPBR in order to enhance the effectiveness, efficiency, and flexibility of alternative licensing for future plants.

## References

[1] Feasibility study for a risk-informed and performance-based regulatory structure for future plant licensing, NUREG-1860, 2007

[2] Proposal for a technical, neutral safety approach for new reactor designs, IAEA-TECDOC-1570, 2007

[3] Design of new nuclear power plants, Draft Regulatory Document RD-337, 2007

[4] Basis for the Safety Approach for Design & Assessment of Generation IV Nuclear Systems, GIF/RSWG/2007/002/Rev. 1, 2008