# Analysis of Risk-Informed Safety Classification for Structures, Systems, and Components of LWRs and Non-LWRs

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## 1. Introduction

Currently, efforts to establish a regulatory framework for non-light water reactors (non-LWRs) are continuously being pursued both domestically and internationally. In the United States, which is leading the way in this regard, improvements are underway to the existing light water reactor (LWR) regulatory frameworks—10 CFR 50 and 10 CFR 52—and 10 CFR 53, which incorporates regulations for non-LWRs, is being developed as a Proposed Rule. As of May 2026, it is scheduled to be submitted to the committee as a Draft Final Rule, with completion targeted for 2027. The newly introduced regulatory framework in 10 CFR 53 features a technology-inclusive regulatory approach, risk-informed performance-based evaluation, and review by an Integrated Decision-Making Panel (IDP) at each detailed stage.

However, a key challenge is that the innovative design characteristics of non-LWRs fall outside the scope of existing regulatory standards for large-scale LWRs, leading to potential licensing issues. Korea has experience in R&D for non-LWRs, and corresponding safety regulations have also been reviewed. Nonetheless, recent technological advancements have not been fully reflected in these reviews, highlighting the need to incorporate global regulatory trends, such as 10 CFR 53, into South Korea's regulatory framework. Since last year, under its implementation plan, the Nuclear Safety and Security Commission has established a strategy to secure regulatory technology for non-light water reactors. Through this plan, government-supported R&D for non-LWRs aimed at developing a proactive regulatory framework has been launched in Korea starting this year.

This paper aims to introduce the technical gap in Structures, Systems, and Components (SSCs) classification between LWRs and non-LWRs, utilizing the Nuclear Energy Institute (NEI) technical report. Since the SSCs safety classification covers a critical step in safety assessment, which involves selecting Licensing Basis Event (LBE) and establishing Required Safety Function (RSF), identifying the technical gap in safety classification is one of the key aspects of non-LWR safety assessment. Through this analysis, the paper seeks to provide reference material for establishing classification criteria in the future development of domestic regulatory technology for non-LWRs.

## 2. LWR SSCs Classification

Under the previous 10 CFR 50.2[1], SSCs were classified solely as "Safety-Related" and "Non-Safety-Related." Table 1 specifies the three functions of Safety-Related components. All SSCs that do not perform the three functions outlined in Table I are classified as Non-Safety-Related.

Table I. Official definition of Safety-Related SSCs

| Safety-Related SSCs function (During and following Design Basis Events) |
|---|
| 1. The integrity of the reactor coolant pressure boundary |
| 2. The capability to shut down the reactor and maintain it in a safe shutdown condition |
| 3. The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures |

NEI 00-04[2] provides actual procedures and methodologies for risk-informed categorization of SSCs for pressurized water reactors, based on 10 CFR 50.69. This document (NEI 00-04) presents safety evaluation and management procedures that maintain design basis accident and severe accident response capabilities by utilizing PSA and the defense-in-depth concept. In accordance with 10 CFR 50.69, Risk-informed Safety Classification (RISC) are used to categorize SSCs into 4 groups. Figure 1 shows the risk-informed safety classification categorization.

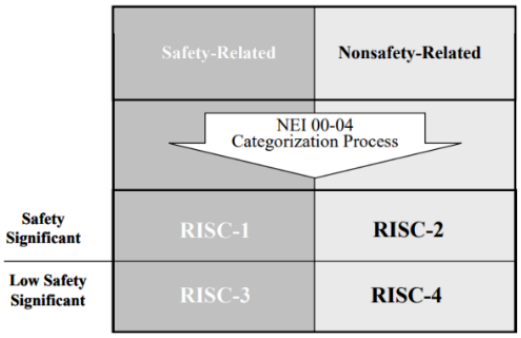


Fig 1. Risk-Informed Safety Classification

As a supplementary information, ANSI/ANS-30.3-2022 [4] is a technical standard that presents the Safety classification for light water reactors through the

utilization of risk information. It aims to classify Safety-Related and Non-Safety-Related systems using PSA results. The key criteria are shown in Table II.

Table II. Key Criteria for LWRs Safety Classification

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|---|
| • The PSA-based risk assessment criteria are divided into Absolute and Relative standards, and are used to evaluate the importance of a specific SSC. |
| • It defines a method for quantifying risk significance and adjusts the Reliability and Availability based on the SSC's risk contribution. |
| • It must reflect the complex risks of multi-unit nuclear power plants and radioactive materials, and the risk contribution can be adjusted according to the scope of the PSA. |

The classification (safety-related or non-safety-related) and categorization (risk-significant or not) described in this standard provides for four groupings of SSCs. The results of SSC classification and categorization should be sorted into at least these four distinct groupings: safety-related SSCs that are risk-significant (Group 1), non-safety-related SSCs that are risk-significant (Group 2), safety-related SSCs that are not risk-significant (Group 3), non-safety-related SSCs that are not risk-significant (Group 4). These four groupings represent a minimum taxonomy for SSC classification and categorization. Further subdivision of these groupings may be performed by the designer or applicant to meet specific design needs within a Risk-Informed, Performance-Based (RIPB) framework. However, grouping thresholds should be sufficiently broad that recategorization of SSCs would not be expected to occur as operating experience is obtained.

## 3. Non-LWR SSCs Classification

NEI 18-04 Chapter 4[3] defines the approach for the safety classification of SSCs for non-LWRs. It demonstrates the process of deriving requirements for SSCs needed to mitigate and prevent Licensing Basis Events (LBEs, i.e., PSFs (PRA Safety Functions)) as modeled in the PRA. This approach employs 10 CFR 50.69. The classification of non-LWRs is divided into three categories, which are listed in Table III.

Table III. Safety Classification for non-LWRs

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| Safety-Related (SR) | • Performs essential functions during a Design Basis Accident (DBA) to limit radiological impacts. Requires high reliability and special treatment. |
| Non-Safety-Related with Special Treatment (NSRST) | • Although not safety-related functions, special measures are needed due to high-risk significance or to ensure adequate DID protection. |
| Non-Safety-Related with No Special Treatment (NST) | • Not directly associated with safety functions and does not have any special regulatory requirements. |

For LWR SSC classification, a deterministic regulatory approach was employed in early days. After accumulating extensive reactor years of operation, PSA started and its results were used to expand the regulatory scope through a "Risk-Informed" approach. In contrast, for non-LWRs, the objective is to establish tailored safety criteria from the design phase based on the specific functions and risk roles of each SSC.

Thus, while LWR safety classification adjusts regulatory applications based on the existing design (deterministic regulation), non-LWR safety classification applies regulatory measures according to the inherent characteristic of the SSCs from the outset.

Furthermore, NEI 18-04 Chapter 4 presents a method for classifying SSCs for non-light water reactors based on the existing 10 CFR 50.69. This method is divided into six steps, as shown in Table IV.

Table IV. SSC Safety Classification (Non-LWRs)

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|---|
| 1. Identification of LBE Prevention and Mitigation Functions |
| 2. Evaluation of DID and Analysis of SSC Roles |
| 3. Definition of RSF |
| 4. Selection of SR SSCs |
| 5. Selection of NSRST SSCs |
| 6. Classification of NST SSCs |

LBE is the overall event sequence considered in the plant's design and licensing basis and may include one or more reactor modules. LBEs encompass AOO, DBE, BDBE, and DBA events. In addition, to ensure DID, the functions performed by the SSCs are evaluated, and the independence and redundancy of these functions are analyzed. Thirdly, RSF is determined based on PSA and the impact assessment during a DBA. These processes are then used to carry out the Safety Classification.

As a supplementary information, NEI 21-07[5] provides guidelines for preparing the Safety Analysis Report immediately prior to the license application. This document (NEI 21-07) focuses on presenting results in terms of the scope and content of the SAR. It also outlines the preparation methodology, assuming adherence to the NEI 18-04 methodology. An SR SSC is a system that performs the reactor's essential safety functions, playing a role in preventing the release of radiation during a DBA. In contrast, an NSRST SSC does not directly perform a safety function but is a device that

plays a critical role in reinforcing DID under certain conditions, thereby requiring additional management. SR SSCs must fulfill the essential safety functions in the reactor design and, similar to those in light water reactors, must satisfy the criteria presented in Table V.

Table V. SR SSCs safety function

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| • Principal Design Criteria (PDC): The PDC must be identified in accordance with 10 CFR 50.34 and 10 CFR 52.79. Plants using the NEI 18-04 methodology may adopt the Required Functional Design Criteria (RFDC), which are derived from the RSFs, as the PDC. |
| • Required Safety Functions (RSFs): Defined based on PRA, RSFs are responsible for mitigating the consequences of all Design Basis Events (DBEs). |
| • Special Treatment Requirements: Includes maintenance, inspection, and environmental requirements necessary to ensure reliability beyond normal industrial practices. Special treatment provides increased assurance that SSCs perform their design-basis functions, as outlined in Regulatory Guide 1.201 and implemented under 10 CFR 50.69. |

## 4. Conclusions

This study analyzed the technical gap in SSC safety classification between LWRs and non-LWRs based on established methodologies such as NEI 00-04, NEI 18-04, NEI 21-07 and ANSI/ANS-30.3-2022. In the case of LWRs, a classification system that comprehensively evaluates the roles, functions, reliability, and availability of SSCs through PSA and DID assessments has been verified. This approach adjusts existing regulations by classifying SSCs into four RISC (Risk-informed Safety Classification) categories.

For non-LWRs, a methodology for SSC classification has been established using the NEI 18-04 document. SSCs can be categorized as SR, NSRST, and NST. This approach distinguishes between SR SSCs, which perform essential safety functions derived from RSF based on PSA analysis and DBA impact assessment, and NSRST SSCs, which do not directly perform a safety function but require additional management to reinforce DID under certain conditions.

The analysis results can be addressed as follows. The safety classification for LWRs adjusts regulatory applications based on the existing design (deterministic regulation), that for non-LWR applies regulatory measures according to the inherent characteristic of the SSCs from the outset.

However, in Korea, even the safety classification for LWRs does not employ a risk-informed approach. This may include institutional shortcomings (e.g., legal issues) and PSA models and reliability data have not yet reached full maturity. Therefore, if the foundation for a risk-informed approach is expanded domestically regardless of reactor type, it will be possible to keep pace with the technical gap. In our next study, we intend to conduct a detailed examination of the domestic safety classification system.

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