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RISK-INFORMED CATEGORIZATION OF THE SSCs IN NPPs

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ABSTRACT

The categorization and treatment of Structures, Systems and Components (SSCs) is a very important part of the license base for Nuclear Power Plants (NPPs). The over-conservativeness of some regulation requirements concerning the categorization and treatment of SSCs based on current deterministic categorization has been recognized by both the nuclear industry and the regulatory body gradually. Therefore, NRC has released the new section 50.69 "Risk-Informed Treatment of Structures, Systems and Components" to amend Title 10 of the Code of Federal Regulations (10 CFR). The pilot study of the risk-informed categorization of SSCs, which is based on the systems in Daya Bay NPP including the survey of methods and the analysis of samples, is presented in this paper.

Keyword: risk-informed categorization importance measure

1. INTRODUCTION

The categorization of SSCs (structures, systems, and components) is one of the cornerstones in the design of the Nuclear Power Plant. In the current deterministic regulations, SSCs are categorized as "safety-related" or "non-safety-related". Safety related SSCs need the special treatment[1] in such areas as quality assurance, environmental qualification, Technical Specifications, 10 CFR 50.59 and ASME code. Special treatment requirements are the requirements imposed on SSCs that go beyond industry-established (industrial) controls and measures for equipment classified as commercial grade, and intend to provide reasonable assurance that the equipment is capable of meeting its design-basis functional requirements under design-basis conditions. As the definition of deterministic categorization, if one system in NPP belongs to the scope of safety-related, all of the components in this system will be defined as safety-related, and the corresponding special treatments will be imposed on them. On the other hand, all of the components in the system that belongs to the scope of non-safety-related will be defined as non-safety-related, and they aren't subject to the special treatments.

As the above description, the regulation requirements based on the deterministic categorization are over-conservative in some aspects, though they were effective in the past years. Hence, it is necessary to optimize and improve the regulatory framework from the viewpoint of risk. NRC has proposed three options for the risk-informed regulatory framework that are known as Option 1,Option 2 and Option 3[2]. In Option 2, it is intended to re-adjust the scope of components requiring special regulatory treatment in order to enhance safety by focusing both the licensee and NRC resources on the components that are significant to healthy and safety, as well as to provide flexibility in plant operation and design, which can result in burden reduction without compromising safety. For this purpose, NRC has released the new section 50.69[3] "Risk-Informed Treatment of Structures, Systems and Components" to amend Title 10 of the Code of Federal Regulations (10 CFR). This section addresses the risk-informed categorization for components and defines the scope of components that should be subject to NRC special treatments by use of risk insights. Some pilot plants such as South Texas Project and Westinghouse Owner Group has initiated the Risk-informed SSC categorization project and submitted their exemption applications for approval.

2. RISK-INFORMED CATEGORIZATION

2.1 the Relationship of Deterministic and Risk-informed Categorization

In the current deterministic regulations, SSCs are categorized as safety-related or non-safety related. The risk-informed categorization does not replace the existing “safety-related” and “non-safety-related” categorizations. Rather, it divides these categories into two subcategories based on high or low safety significance. This method combines the successful engineering experience with the insight of PSA. It can make the managers to focus on the every system or component which has real impact on the safety of NPPs. The relationship of the two categorizations scheme is depicted in Figure 1[1].

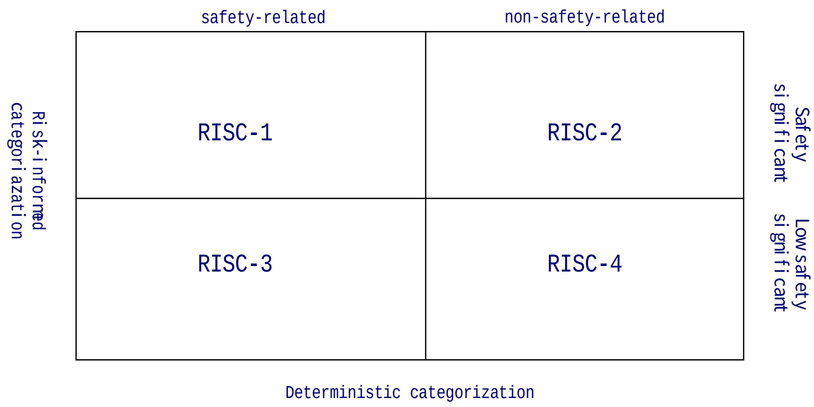

Figure 1 Risk-Informed Safety Categorization (RISC)

Risk-Informed Safety Categorization (RISC)-1 SSCs are safety-related SSCs that perform safety-significant functions.

RISC-2 SSCs are non-safety-related SSCs that perform safety-significant functions.

RISC-3 SSCs are safety-related SSCs that perform low safety-significant functions.

RISC-4 SSCs are non-safety-related SSCs that perform low safety-significant functions.

Safety-significant function is a function whose degradation or loss could result in a significant adverse effect on defense-in-depth, safety margin, or risk. Under risk-informed categorization, SSCs of low safety significance would move from "special treatment" to normal industrial (or "commercial" treatment), but would remain in the plant and be expected to perform their design function but without additional margin, assurance or documentation associated with high safety significant SSCs.

2.2 Example of South Texas project

Some pilot plants have initiated the Risk-informed SSC categorization projects and have gained some effective results, such as Surry NPP Unit 1 and Wolf Creek NPP (by Westinghouse Owners Group (WOG))[4], South Texas project (STP) [5], Ulchin NPP Unit 3 in Korea[6], Sizewell B NPP in U.K[7], and PCCV 4-Loop PWR in Japan[8]. The application by WOG will be discussed following sections.

South Texas project has initiated the Risk-informed SSC categorization project and some exemption applications have been submitted to NRC for approval. South Texas Project PSA is a full power level 2 PSA, including internal and external initial events. The risk-informed categorization is applied to the all systems in plant and the results are depicted in Table 1.

Table 1 The risk-informed results of South Texas Project

Deterministic categorization	Safety-related		Non-safety-related	
Risk-informed categorization	RISC-1	RISC-3	RISC-2	RISC-4
Number	4197	13325	393	29906
Percentage	8.8%	27.9%	0.8%	62.5%

As shown by the application results, a large number of safety-related components can be re-categorized to RISC-3 and some of non-safety-related components can be re-categorized to RISC-2. For the components in RISC-3, it would be very much possible to move them from the special treatment requirements to the normal industrial requirements to reduce the burden without compromising safety. On the other hand, for the components in RISC-2, it would be necessary to enhance the current requirements imposed on them to guarantee the nuclear safety. Therefore, the risk-informed categorization brings the two benefits primarily as follows:① Reduce the management burden for the RISC-3 components,② Enhance the safety level of NPP by focusing resources on the safety significant components including enhancing the requirements for RISC-2 components.

3. THE METHOD OF RISK-INFORMED CATEGORIZATION

The risk-informed categorization is an integrated decision-making process. It uses both probabilistic and deterministic based methodologies that appropriately addressed the issues of defense-in-depth, safety margins, and aggregate risk impacts. STPNOC.s risk-informed categorization process evaluates the risk significance of individual SSCs using a two-fold process:① a process using PRA information, and ② a deterministic risk ranking process based on expert judgment. Under this dual process, if the SSC is modeled in the PRA, it is separately rated based on the two independent processes. The higher of the two ratings is then used as its final categorization. If the SSC is not modeled in the PRA, it is rated using the deterministic risk ranking process. And the process categorize the SSCs into four categories that are HSS(High Safety Significance), MSS(Medium Safety Significance), LSS(Low Safety Significance),and NRS(Non-risk Significance). The HSS and MSS SSCs are belong to risk significance and the LSS and NRS SSCs are belong to non-risk significance.

- Risk Categorization Process Based on PRA Information

The relative importance of SSCs modeled in the PRA is determined using two PRA importance measures: Fussell-Vesely (FV) and Risk Achievement Worth (RAW). The FV importance provides a measure of how much of the total sequence frequency is due to minimal cutsets that contain the specific event or SSC for which the FV importance measure is to be calculated. The RAW importance measure is an indicator of how much the sequence frequency would increase if it were assumed that an SSC would fail.

The importance measures of SSCs are compared to guideline values that are consistent with the provision of RG 1.174[9] and the safety-significance category for each SSC determined. The values and categories are depicted in Table 2.

Table 2 the result of PRA categorization process

Risk Significance Ranking	Criteria
High (HSS)	RAW≥100.0 OR FV≥0.01 OR FV≥0.005 and RAW≥ 2.0
Medium (further evaluation required)	FV<0.005 and 100.0>RAW≥10.0
Medium (MSS)	FV≥0.005 and RAW<2.0 OR FV<0.005 and 10.0>RAW≥2.0
Low (LSS)	FV < 0.005 and RAW < 2.0

Note: Only SSCs not modeled in the PRA can be placed in the NRS category.

- Deterministic Risk-Ranking Process

Regardless of whether an SSC is subject to the risk-ranking process using PRA insights, under this categorization process all SSCs are subject to a deterministic risk-ranking process. The first step consists of the Working Group identifying the system functions performed by the selected plant system. Next, each component in the system is evaluated to identify the system function(s) supported by that component.

In categorizing the functions of a system, the Working Group considers five critical questions regarding the function, each of which can be answered by a score ranging from zero to five according the impact on safety if the function is unavailable and the frequency of loss of the function. A score from each critical question is then multiplied by a weighting factor for each question. Finally, categorize the SSCs according to their final scores that are gained by summing this five individual scores. These questions and their weight are depicted in Table 3.

Table 3 critical questions and weight

Critical Questions	Weight

Is the function used to mitigate accidents or transients?	5
Is the function specifically called out in the emergency operating procedures or Emergency Response Procedures (that provides beyond design-basis configuration)?	5
Does the loss of the function directly fail another risk-significant system?	4
Is the loss of the function safety significant for shutdown or mode changes?	3
Does the loss of the function, in and of itself, directly cause an initiating event?	3

In general, the SSC are assigned the same risk category as that of the most highest category system function that the SSC supports. However, the SSC can be ranked than the associated system function(s) when there are redundant or diverse means of satisfying the system function. However, merely having multiple trains of components available in a system does not automatically result in that component being assigned to a lower category. In addition, the final category of an SSC cannot be NRS if the system function is LSS (or higher), and generally cannot be more than one category level lower than the category of the most limiting system function.

4. CASE STUDY IN DAYA BAY NPP

In this paper, the Daya Bay NPP of china is selected as the sample plant in order to study the application of risk-informed categorization. This plant is a two unit, three-loop PWR rated at 1000Mwe each copied from France. It has the full power, internal events PSA.

In this plant, the auxiliary service water system (ASG) and high-pressure safety injection system (HRIS) are selected for the pilot study. According to the current deterministic categorization, ASG/HRIS system is "safety-related". Only the components modeled in the PSA are studied in this project. In this PSA model, 75 and 147 components have been modeled in the system ASG and HRIS respectively. The results are depicted in Table 4.

Table 4 The risk-informed results of Daya Bay Project

Deterministic categorization	Risk-informed categorization	Number	
		ASG	HRIS
Safety-related	RISC-1	18	56
	RISC-3	57	91

As shown by the results, a large number of safety-related components can be re-categorized to RISC-3. Therefore, the results accord with the expectation based on the risk-informed categorization.

5. CONCLUSION

According to the above sections, the results of risk-informed categorization can not only enhance safety by focusing the resources on the components that are significant to healthy and safety, but also provide flexibility in plant operation and design, which can result in burden reduction without compromising safety.

This categorization method has been developed in USA for many years, but its development in china nuclear industry has stayed at initial stages. The pilot study in Daya Bay NPP include in the paper intend to promote the application of risk-informed categorization in china. According to the fact of china nuclear power plant, many aspects should be studied in the future, such as the level of some plants' PSA should be enhanced to match the requirements of categorization, how to select the thresholds of risk importance measure, etc.

In a word, the risk-informed categorization is very useful for reducing the management burden and cost, enhancing the economical benefit of NPPs. But its application in china needs more studies and effort to promote.

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