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Scoping and selection of safety significant structures, systems and components for containment spray system

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1. Introduction

In a nuclear power plant, there are several systems that are relied upon to perform both safety and non-safety related functions. Within each system, there are hundreds of components that perform various functions to meet the system high level goal. It is not economically possible to have all these components monitored under the maintenance rule. In order to optimize the maintenance strategy, selection and scoping of functions is critical. The functions that are important to safety are given first priority so as to mitigate the plant against postulated accidents.

This paper seeks to apply maintenance rule guidelines to establish the functions and determine the safety significance SSCs for a containment spray system (CSS). This strategy allows the Nuclear Power Plant (NPP) operator to prioritize its resources on the most critical SSCs and improve operability, reliability and availability of SSCs in a cost effective manner.

2. Maintenance Rule operationalization

In South Korea, KHNP started implementing MR in 2003 with the pilot projects of KORI 1&3 and Ulchin 3&4. The pilot projects for Wolsong 3&4 and Wolsong 1&2 were carried out in 2007 and 2009 respectively [2]. For the case of USA, USNRC published 1996 as the full implementation year for the MR by all utilities [1]. However, there had been earlier implementation of maintenance rule by nine power plants and the lessons leant on the plant's performance were so impressive [5]. In Canada, the Canadian Nuclear Safety Commission (CNSC) issued a standard similar to US NUMARC 93-01 called S-98 Rev 1 "Reliability Program for NPPs" [2]. Effective monitoring of the performance of SSC is important in ensuring that failures of structures, systems, and components (SSCs) other than safety-related SSCs that could initiate or cause a transient or accident are minimized.

3. Methodology

The process is described in the following steps; identification of important functions that are performed by the system , scoping of the identified system's functions, determination of risk significant functions using both probabilistic safety assessment and Delphi methods [1]. The maintenance rule is applied as follows;

3.1 Scoping

The functions performed by the containment spray system for OPR 1000 were identified from system design bases documents, system description, FSAR. The functions are analyzed and categorized according to their importance as follows [4];
CS-01: Cooling and depressurizing the containment atmosphere after the accident.
CS-02: Removing the radioactive fission products from the containment atmosphere.
CS-03: Providing a backup to the Shutdown Cooling pump when it is unavailable.
CS-04: Isolating the mini-recirculation line.
CS-05: Isolating the Containment.

The containment spray system is determined whether it is within the scope of maintenance rule using figure 1 [1].Table I shows scoping of functions. Functions CS-01, CS-02, CS-04, CS-05 are safety related three (SR3) while CS-03 is safety related two (SR2) because of its application in shutdown and maintaining safety shutdown. NSR refers to non- safety related functions. All the functions analyzed were found to be within the scope of the maintenance rule.

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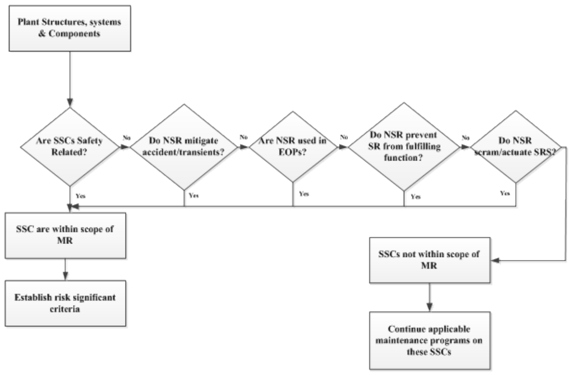

Figure 1 SSC scope determination logic diagram

<Table I> CSS Functions Scoping

ID	SR1	SR2	SR3	NSR1	NSR2	NSR3	NSR4	Scope
CS-01	N	N	Y	N	N	N	N	Y
CS-02	N	N	Y	N	N	N	N	Y
CS-03	N	Y	N	N	N	N	N	Y
CS-04	N	N	Y	N	N	N	N	Y
CS-05	N	N	Y	N	N	N	N	Y

3.2. Determination of safety significance functions

The establishment of safety significance of the in scope system's functions was performed using probabilistic safety assessment and Delphi methods. These are the main tools provided in the NUMARC 93-01 guidance. PSA analysis is quantitative and performed for components that are modeled as basic events in PSA. The high risk significance of the basic event (component) as determined by the PSA was linked to the specific MR function flow-path in which the component falls in.

The PSA determination of high safety significance was based on risk achievement worth (RAW) greater than 2.0, risk reduction worth (RRW) greater than 1.005, or the cumulative core damage frequency (CDF) greater than 90% of the total CDF [1]. Owing to some limitation of PSA not all system's functions could be modeled quantitatively and therefore the other method called Delphi was applied to determine the safety significance of the all the functions qualitatively. This method utilized the expert panel that consisted of the site MR coordinator, operation engineer, maintenance engineer, systems engineer, risk expert (PRA), and design engineer.

In this method, the expert panelists score the importance of all in-scoped functions against the accident response functions criteria. The process is performed in three rounds to ensure objectivity of the individual panelist. The weighted score limit for high safety significance (HSS) was set at point greater than 362 (industry wide upper limit for high safety significance function using the EPRI calculator model). Figure 2 shows the safety significance determination process for the containment spray system. Second Delphi is necessary when the panelists are not satisfied with first results showing LSS scores.

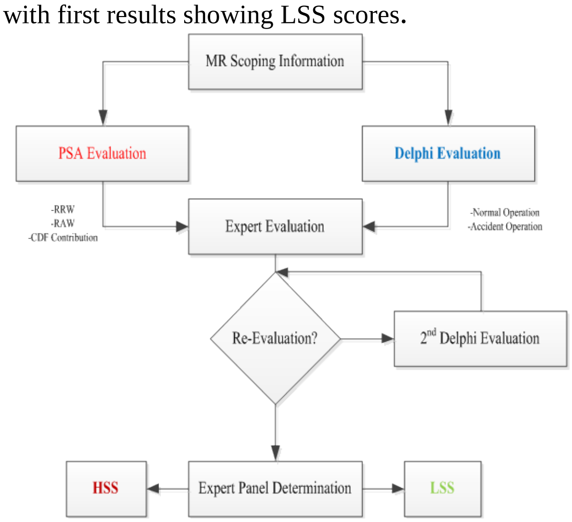

Figure 2 Safety significance determination flow diagram

4. Results

The result of safety significance determination for the containment spray system is described in table II. The expert panel evaluated 20% of the functions to be HSS while 80% are LSS. The PSA results are extracted from basic events of the important measures while Delphi results from Delphi evaluation sheet.

<Table II> Safety significance criteria results

System description		Containment spray system (OPR1000)
No of Functions		5
PSA results	HSS	2
	LSS	3
Delphi results	HSS	1
	LSS	4
Final expert panel	HSS	1 (20%)
(EP) determination	LSS	4 (80%)

Table II indicates that the PSA determined functions; CS-01 and CS-03 to be high safety significant while CS-02, CS-04, and CS-05 are low safety significant. However, Delphi evaluation evaluated CS-01 to be high safety significant while the other four functions are deemed low safety significant.

The expert panel analyzed the outcomes of both evaluations and finally made a decision that CS-01 is HSS while CS-01, CS-02, CS-03, CS-04, and CS-05 are low safety significant functions.

5. Conclusion

The scoping process shows that function CS-01 is high safety significant and therefore it is necessary that effective monitoring of the responsible SSCs to ensure reliable operation when demanded.

In this analysis, the PSA determines two functions to be high safety significant while Delphi considers only one function critical. The final expert decision holds that only one out of the five functions is high safety significant.

The high safety significant function (CS-01) should have both reliability performance criteria (RPC) and availability performance criteria (APC) set as the performance criteria while the low safety significant functions (CS-02~05) should only have APC as their performance evaluation.

REFERENCES

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[4] OPR1000 System description, Reactor and Auxiliary system KHNPHRDI. Handbook.

[5] Lessons learnt from early implementation of the maintenance rule at nine Nuclear Power Plants-NUREG/CR-1526.