Scoping and Safety Significance Analyses for CANDU System Maintenance Effectiveness Monitoring

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1. Introduction

Korea Hydro & Nuclear Power Co. (KHNP) is developing the maintenance effectiveness monitoring program, called Maintenance Rule (MR) program in the US, both for PWRs and CANDU reactors although the MR is not a part of safety regulation yet in Korea. Especially, it is the first time to develop a MR program for CANDU systems in the world. At the present, the scoping and safety significance determination have been completed, and the performance criteria, which is the next step, is in progress.

In this paper, the characteristics of CANDU systems and technical considerations for performance criteria establishment are presented in comparison with the scoping and safety significance determination made for PWRs.

2. Application of the Concept of the Maintenance Rule to CANDU Systems

The MR program was initiated by the US NRC and implemented according to NUMARC 93-01 as a guideline in the US. Since there are only LWRs in the US, the NUMARC93-01 has never been applied for the CANDU reactor type. In the meanwhile, Canadian Regulatory body, Canadian Nuclear Safety Commission (CNSC), issued a similar standard which is S-98 Rev.1 "Reliability Program for NPPs". It requires specific reliability targets for safety systems. Another standard issued by CNSC, S-210, "Maintenance Program for NPPs", includes a requirement of monitoring the effectiveness related to maintenance program. These regulatory documents, however, are not supported by implementing guidelines like NUMARC 93-01 to practically develop a program.

Because NUMARC 93-01 provides procedural guidelines to develop a program to ensure the reliability of equipment as required by the MR, it can be used irrespective of reactor types.[1]

Therefore, NUMARC 93-01 guideline was applied as a basis to the MR program development for CANDU systems. Nevertheless, the characteristics of CANDU systems was considered and examined for applicability of the NUMARC93-01.[2]

3. Comparisons with LWR programs

The Maintenance Rule program is developed through a three stage process, scoping, safety significance determination, and performance criteria establishment.

In this section, the characteristics of CANDU systems that were examined in detail for the program development are discussed in comparison with the scoping and safety determination of the LWR program.

3.1 Scoping

While analyzing the functions based on the design documents which are FSAR, system manuals and etc., several characteristics of CANDU systems were identified for scoping analysis as follows;

1) CANDU Systems are classified as 1, 2, 3, 4, S and 6 according to their safety roles whereas LWR systems are categorized as safety and non-safety classes,

2) There are systems unique to CANDU reactors; the moderator system, refueling system, reactor core consisting of fuel channels, digital control system, etc,

3) The RCS pressure boundary changes depending on the operation modes due to the on-line refueling,

4) For some of the systems, system boundaries are defined differently than PWRs.

To determine the scope of monitoring for CANDU systems, the functions of a system needed more careful analyses for the precise application of the scoping criteria in NUMARC93-01, as many of the CANDU systems classified for safety functions also carry out normal operating roles as well. Nonetheless, no obstacle was found in applying them to CANDU. Figure 1 shows a comparison of scoping analysis results between CANDU and PWRs. It is noticed in Fig. 1 that the number of systems and functions identified in CANDU is larger than that of PWRs.

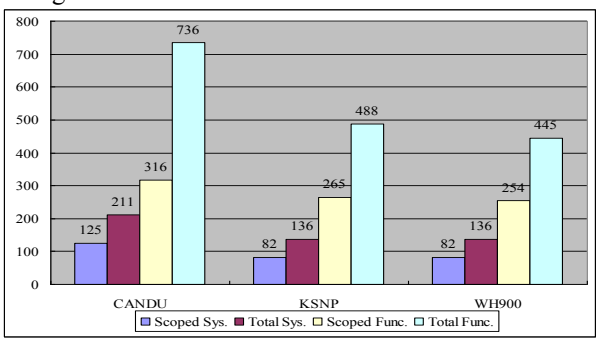

Figure 1: Comparison of the Number of Scoping Systems and Functions between CANDU and PWR

Table 1 shows a more detailed comparison of function analysis results.

Compared with the PWR cases, some of the characteristics of CANDU systems resulting in such a larger number of identified and in-scoped functions are:
1) The number of identified and scoped functions in NSSS area is much more than that of LWR, because the primary system of CANDU is more complex, i.e., the multiple pressure tube type reactor system consists of the End Shield Cooling, Annulus Gas and Liquid Zone Control systems for reactor regulation.
2) CANDU is equipped with additional systems due to its design characteristics such as systems to treat heavy water and to refuel by on-line
3) The functions of I&C for process systems are configured as separate systems.

Table 1: Comparison of Identified Functions in areas

	CANDU	KSNP	WH900
NSSS	91/288	68/119	89/153
BOP	86/224	93/219	67/156
I&C	43/105	42/67	26/45
Elec.	73/94	62/83	72/91
Fuel	8/25	-	-
Total	316/736	265/488	254/445

*(In-scoped / Total Functions)

3.2 Safety Significant Determination

Safety significance of in-scoped functions was determined by use of Probabilistic Safety Analysis (PSA) and Delphi assessment following the NUMARC93-01 guidance. To apply PSA results to the safety significance determination, the same criteria that were applied for the PWR case were used. For determination of High Safety Significant (HSS) function, the criteria of RAW greater than 2.0, RRW greater than 1.005, or the cumulative CDF greater than 90% of the total CDF were used.

The other method using Delphi assessment utilized Expert Panel consisting of plant staff with expertise in systems, PSA, operation, and maintenance. In the Delphi method, the panel members should score the importance of the in-scoped functions to the criteria defining basic roles of functions for the accident response or normal operations. Due to the unique features of the CANDU systems, three more criteria are added to the Delphi criteria used for the PWRs. They are; (1) the importance for reactivity control under normal operation, (2) the importance for fuel transfer and refueling, and (3) the importance for plant control signals. The threshold point above which a function should be determined to be HSS was set to be 340 which was lower than the point applied for the PWRs.[3]

The result of safety significance determination is summarized in Table 2. Among the 316 in-scoped functions, 139 functions were determined as HSS. The percentage of HSS is higher than that of PWRs.

Comparing to the results of significance determination for LWR, the difference may be due to the following reasons;

1) Most of functions identified for Class 1~4 and S components were classified as safety functions. Many of these systems perform safety and non-safety functions all together. For conservatism, these were classified as HSS functions.
2) The number of functions determined by PSA was less. The initial events were not considered in safety significance determination.
3) The percentage of HSS determined by Delphi assessment was less. As many of CANDU systems perform non-safety functions with safety class equipment and functions were more divided than PWRs, it is speculated that the Expert Panel members would have a tendency to give low importance to the functions.

Table 2: Comparison of Safety Significant Determination Results

		PHWR	KSNP	WH900
Total Functions		316	260	241
PSA	High	41	85	59
	Low	56	108	100
Delphi	High	129	140	116
	Low	187	120	125
Final	High	139(44%)	97(37%)	88(37%)
	Low	177(56%)	163(63%)	153(63%)

4. Conclusions

As NUMARC 93-01 is a procedural and conceptual guideline, it was applicable to CANDU systems. Because there are differences in system configuration and design features, however, careful application of criteria given in NUMARC93-01 for scoping functions were required, and modification of the Delphi assessment for safety significance determination was needed.

The scoping and safety significance analyses resulted in a larger number of systems and functions, and higher ratio of HSS functions in CANDU than PWRs due to the characteristics of CANDU systems. In view of the number of in-scoped functions and the results of safety significance determination, the performance criteria would be defined with relatively narrow monitoring scopes in general, compared with those for PWRs. In the next step, performance criteria will be studied to monitor the system, function and component effectively.

REFERENCES

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