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Scoping Process in Maintenance Rule Development for PHWR

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1. Introduction

It has been recognized that the Maintenance Rule (MR) program is an effective tool for maintenance and management of the important SSCs (Structures, Systems and Components), which could affect the plant safety or cause the trip, by means of setting up and monitoring the performance program. It was also recognized as an essential tool for performance monitoring in risk informed decision making (RIDM) and optimization in nuclear power plant.

In Korea, two pilot programs development for PWR MR were already completed and now its extension project to all PWR is underway. However, in case of PHWR (CANDU type, Wolseong Unit 1,2,3 & 4), the study of MR program was delayed, since the design concepts and operating experiences are different from those of PWR. Additionally, in Canada that designed the CANDU reactor originally, the MR program has not been tried even though the similar programs such as the Reliability Program [1] and Maintenance Program [2] exist. In 2007, KEPRI started a project for developing similar MR program for the domestic PHWR considering the unique design characteristics and operating experience of Wolseong Unit 1,2,3 & 4.

This paper describes the characteristics of CANDU design experienced during the scoping process, first step in MR program development, and the results of scoping process.

2. Scoping Process

Based on the Design Manual, FSAR, and PSA report, the function analysis for SSCs of Wolseong Unit 3&4 was performed according to their system BSI (Basic Subject Index) classification. The functions identified in functional analysis were classified as SR-1/2/3 and NSR-1/2/3/4, using the criteria based on Reference [3],[4], and [5]. The criteria for classification of SR & NSR are related to the design principles based on the defense in depth philosophy. Since the design features of CANDU is different from those of PWR (for example, using D_2O as a coolant and moderator, the pressure tube and Calandria, and the fuel changing machine, etc.), the adaptation of PWR criteria to CANDU had to be investigated and justified.

2.1 Criteria for SR/NSR Classification

The first step of SR (safety related) & NSR (non-safety related) classification in scoping process involved the review of the system design class. The second step included deciding whether the each function in a system is SR or NSR [6]. However, it was noted that the system safety class designation can be different than the MR functional class for some systems. In other words, though one system is designed as safety class, this system can have the NSR function. And, inversely, some non-safety systems can perform the SR function. So, it cannot be considered that all functions in a safety system composed of safety function. The criteria for SR-1/2/3 and NSR-1/2/3/4 in MR are not focused on the SSC design class but its functional requirements.

In the case of CANDU, the original design class was designated by the Class 1,2,3,4,S,6 for each component, instead of system. In later stage, the systems were re-classified with SR and NSR according to Safety Design Guide by AECL and MOST Notice 2002-21. Therefore, it may create additional confusion to the station engineers when a different SR and NSR classification based on the functional requirements from MR is introduced, without a clear guidance and explanations.

By this reason, each function of all systems in Wolseong Unit 3&4 was classified using only the functional requirements according to the core principles of MR program. Later, it is expected that the resolution on this classification issue will be derived based on a further investigation.

2.2 SR evaluation Characteristics in PHWR

The SR category is directly related with the defense in depth philosophy. The first criterion in the scoping process is SR-1, "Safety-related SSCs that are relied upon to remain functional during and following design basis events to ensure the integrity of the reactor coolant pressure boundary." A close observation is needed in SR-1 evaluation, since the primary system design of CANDU is significantly different from that of PWR. The pressure boundary in Heat Transport System (RCS) is bounded by HTS itself and the first isolation valve in all systems connected to HTS, per FSAR. The systems including SR-1 function are Fuel channel assembly, Calandria and end shields, Moderator cover gas system, Steam Generator, Main heat transport circuit, D_2O feed and bleed system, Pressure Control system, Gland seal circuit, PHT Purification system, Shutdown cooling system, D_2O Sampling system, ECCS, Annulus gas system, Fuel changing machine, Gaseous fission product monitoring system, and Failed fuel location system. The Moderator system, which is the unique feature in CANDU, does not include SR-1 function because it is separated from HTS loop. So, Safe Shutdown System #2 (SDS#2) which injects the poison into Moderator

system also does not include SR-1 function. The Fuel Changing Machine, another unique feature in CANDU, contains SR-1 function since the CANDU changes fuel during power operation using fuel changing machine and, at this time, the HTS pressure boundary was included in Fuel Changing Machine.

The second criterion is SR-2, "Safety-related SSCs that are relied upon to remain functional during and following design basis events to ensure the capability to shut down the reactor and maintain it in a safe shutdown condition." Simply, it corresponds to the function injecting and maintaining the negative reactivity, such as the shutoff rod drop function in SDS#1 and the poison injection function in SDS#2. Also, there are some SR-2 functions included in Main moderator system, Moderator purification system, and Liquid poison addition system.

The third criterion is SR-3, "Safety-related SSCs that are relied upon to remain functional during and following design basis events to ensure the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the 10CFR100." This criterion constitutes two functions; one is preventive function that removes the residual heat from HTS and core, and the other is mitigate function that isolates the release of the radioactive material to environment and maintains the containment integrity. The systems with SR-3 functions are similar to those of PWR.

2.3 NSR evaluation Characteristics in PHWR

The NSR-1/2/3 criterion was similarly applied with that of MR program for PWRs.

The NSR-4 criterion is the "Nonsafety-related SSCs whose failure could cause a reactor scram or actuation of a safety-related system." In CANDU system, the reactor does not promptly tripped in case of turbine trip by Step-Back and Set-Back operation. So, the general rules representing these characteristics were set up for NSR-4 evaluation as described below.

The NSR-4 was re-designated such that the functional failure can cause;

1) a trip or actuation of safety system on the basis of utility specific or industrywide operating experience
2) a trip or actuation of safety system confirmed by utility safety analysis (FSAR, PSA, EQ, etc.)
3) a direct trip (auto) excluding the diversity and redundancy
4) a power reduction by Technical Specification Limit Condition for operation.
5) a power reduction below 60% of reactor power

But, the maintenance shutdowns due to functional failure were excluded in NSR-4 evaluation, and emergency function against the failure of normal function was considered in non-safety system.

According to these rule, the trip history of Wolseong units was investigated and mapped into functional analysis except the trip related with human error and external events.

3. Scoping Results and Conclusion

On the basis of above classification criteria, the function analysis for all systems of Wolseong Unit 3&4 was performed. And the final determination for scoping results was confirmed by Expert Panel organized by the plant expert engineers of Wolseong Unit 3&4. As shown in Table 1, the total number of system based on the BSI number is 484, and the total number of function is added up to 1053. Among these functions, 339 functions were evaluated as "N/A" (Not Available) because some functions were not used in Wolseong Unit 3&4 or others were transferred or merged into other functions [7].

Through the discussion in three separate expert panel meetings, 129 functions are designated as SR function and 179 functions are designated as NSR function, so the total numbers of 308 functions are determined as in-scope functions and the remaining 406 functions are identified as out-of-scope functions within the Maintenance Rule.

Table 1. Scoping Results

In Scope: 308(43%)		Out of Scope	N/A
SR	NSR		
129(18%)	179(25%)	406(57%)	339

Going forward, the safety significance determination process will be performed and the performance criteria will be established, based on these scoping results,.

REFERENCES

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[6]KEPRI, R-2003-A-232 "Development of Monitoring Technologies for the Effectiveness of Maintenance at KSNP," Final Report, 2006.11

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