Analysis of Normal Operation Function Effect on Qualitative Risk Importance in CANDU

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1. Introduction

Development of the Maintenance Effectiveness Monitoring Program consists of three major steps: scoping functions, determining importance and establishing performance criteria. Once the scoping of functions is completed, those functions are categorized into High Safety Significance (HSS) or Low Safety Significance (LSS) according to their importance.

The Maintenance Rule (MR), which is U.S. 10CFR 50.65, monitor the safety related systems and their support system's performance in Light Water Reactor (LWR) plants. Industry guidance for the development of the MR program provides instructions only for PWR plants and does not mention CANDU plants.

CANDU systems are different from PWRs in many aspects. In developing CANDU MR, it was necessary to reflect the specific characteristics of CANDU and compare them with PWR functions.

Industry guidelines provide a method to provide a method to determine risk importance. [1] KHNP adopted a combination of two different approaches: qualitative risk analysis using expert judgment and quantitative risk analysis using the Probabilistic Safety Analysis (PSA).

This paper presents the effect of three additional Normal-Operation (NO) function questionnaires added for CANDU for determining the qualitative risk importance.

2. Methods and Results

This section describes the MR risk importance categorization methodology and the effect of the three questionnaires developed for the CANDU program for qualitative risk importance determination.

2.1 Risk Importance Categorization of MR functions

Industry guidelines suggest developing risk significance criteria using any of following methods:

- Individual Plant Evaluation (IPE),
- Plant specific Probabilistic Risk Assessment (PRA),
- Critical safety functions (e.g., vessel inventory control) system performance review,
- Other appropriately documented processes

The IPE and PRA methods are quantitative methods and the other two methods are qualitative methods.

The Korean nuclear industry adopted the PSA method and the Delphi method introduced in NUMARC 93-01 chapter 9.3.1.

The PWR MR program at KHNP uses a risk significance method similar to that used in the U.S. industry. NUREG/CR-5695 "A Process for Risk Focused Maintenance" provides Delphi questionnaires for qualitative importance determination which consist of four accident response functions and six normal operation functions as shown as table 1.

Table1. Questionnaires for MR qualitative Risk Importance Determination for PWR plants

Questionnaires
Accident Response Function - Required to shutdown the reactor and maintain it in a safe shutdown condition? (AR-1) - Maintain the reactor coolant pressure boundary?(AR-2) - Remove atmosphere heat and radioactivity from containment and maintain containment integrity? (AR-3) - Remove heat from the reactor? (AR-4)
Normal Operation Function - Required to provide primary side heat removal?(NO-2) - Required to Power conversion?(NO-3) - Provide primary, secondary, or containment pressure control?(NO-4) - Provide cooling water, component or room cooling? (NO-5) - Provide electric power (AC, DC)? (NO-6) - Provide other motive or control power(instrument air) ?(NO-7)

As a result of a previous CANDU MR development project for Wolsong Unit 3&4, three additional Delphi questionnaires were developed. All of them are normal operation functions as shown as table 2. [2]

Table 2. Additional questionnaires for qualitative Risk Importance Determination of CANDU plant

Normal Operation Functions
- Required to regulate reactor power? (NO-1) - Required to change and transfer reactor fuel? (NO-8) - Provide signal for plant control? (NO-9)

2.2 Result of Delphi Risk Importance Determination

Plant experts determine the risk importance of the functions included in the MR using the 13 CANDU specific Delphi questionnaires.

The result of Delphi risk importance determination for Wolsong Unit 1&2 is presented in table 3. Among the 288 MR functions, 125 functions are considered as HSS functions by the Delphi method. The other 163 functions are categorized as LSS.

Table 3. Risk Importance result by the Delphi method for Wolsong 1&2 MR functions

	HSS	LSS	Total
Delphi result	125	163	288

For the further analysis of the influence of additional normal operation questionnaires, the functions are investigated to determine which questionnaire is most effective for each function. Plant experts assign points between 1 and 10 according to their importance to the questionnaire. If the functions are bigger than 6 points, it means the function plays an important role for that questionnaire. Table 4 shows the number of functions matched to each questionnaire.

Table 4. Number of functions matched to the Delphi questionnaires

Delphi questionnaire	Total	HSS	LSS
AR-1	40	29	11
AR-2	21	14	7
AR-3	31	7	24
AR-4	71	64	7
NO-1	9	1	8
NO-2	15	6	9
NO-3	37	3	34
NO-4	15	7	8
NO-5	24	6	18
NO-6	47	27	20
NO-7	7	2	5
NO-8	11	2	9
NO-9	18	13	5

Among the 38 functions greater than 6 points at NO-1, NO-8 and NO-9, 16 functions are determined as HSS. For a detailed evaluation of influence of additional questionnaires, those HSS functions are reviewed.

The functions important for NO-9 are re-evaluated to see the influence on the function's risk significance by setting the NO-9 to point 1. The 16 functions are still HSS without NO-9 point. The three functions considered important for NO-1 and NO-8 get same result except for one function. This means there is no influence by adding three additional questionnaires.

2.3 Risk Significance Influence of Normal Operation Function

As the above result demonstrates, three additional normal operation function questionnaires did not affect the risk importance of the functions. The reason for this result is that those three additional questionnaires are normal operation functions and the normal operation function questionnaires are assigned smaller weighting factors than accident response function questionnaires as shown in figure 1.

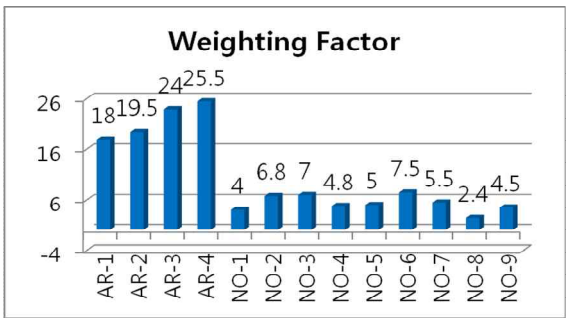

Figure1. Delphi weighting factors for CANDU plants

Among the 125 Delphi HSS functions, 100 functions are still HSS functions without NO-1-NO-9 points. Only in 25 functions, NO1-NO9 questionnaires contributed to qualitative risk importance. In many cases, the AR-1-AR-4 are dominant factors in determining the qualitative importance in CANDU MR.

3. Conclusions

The KHNP MR program adopted two different risk importance analysis methods: the PSA method and the Delphi method.

As a result of previous MR development projects, CANDU specific Delphi questionnaires were introduced. The questionnaires consisted of four accident response functions and nine normal operation functions. The functions were categorized into HSS and LSS by applying the questionnaires.

The accident response function questionnaires usually get much bigger weighting factors than normal operation functions and are major contributors to importance because the Delphi's purpose is to find which function is important for safety.

The three additional questionnaires of CANDU MR are normal operation functions and have small weighting factors. The added NO-1, NO-8, NO-9 normal operation function questionnaires are not major contributors to determine risk significance.

REFERENCES

[1] Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants, NUMARC 93-01 *Revision 3*, NEI, July 2000

[2] Development of Instruction for evaluation of qualitative importance and setting the threshold value, KAERI, 2008