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Development of Web-Based Common Cause Failure (CCF) Database Module for Nuclear Power Plants

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1. Introduction

Probabilistic safety assessment (PSA) has been used to identify risk vulnerabilities and derive the safety improvement measures from construction to operation stages of nuclear power plants. In addition, risk insights from PSA can be applied to improve the designs and operation requirements of plants.

However, reliability analysis methods for quantitative PSA evaluation have essentially inherent uncertainties, and it may create a distorted risk profiles because of the differences among the PSA models, plant designs, and operation status. Therefore, it is important to ensure the quality of the PSA model so that analysts identify design vulnerabilities and utilize risk information. Especially, the common cause failure (CCF) has been pointed out as one of major issues to be able to cause the uncertainty related to the PSA analysis methods and data because CCF has a large influence on the PSA results.

Organization for economic cooperation and development /nuclear energy agent (OECD/NEA) has implemented an international common cause failure data exchange (ICDE) project for the CCF quality assurance through the development of the detailed analysis methodologies and data sharing. However, Korea Hydro & Nuclear Power company (KHNP) does not have the basis for the data gathering and analysis for CCF analyses.

In case of methodology, the Alpha Factor parameter estimation, which can analyze uncertainties and estimate an interface factor (Impact Vector) with an ease, is ready to be applied rather than the Multi Greek Letter (MGL) method.

This article summarizes the development of the plant-specific CCF database (DB) module considering the raw data collection and the analysis procedure based on the CCF parameter calculation method of ICDE.

2. Design Strategy of Web-Based CCF Module

The web-based CCF module basically has been designed according to the general guidelines for the CCF analysis of ICDE. For application of the Alpha Factor method, which is commonly adopted in the CCF analysis, this new module uses failure data collected from plant reliability data information system (PRiNS) that has been already developed. The web-based CCF module follows all necessary requirements for CCF parameter estimation in the ICDE project.

The design stages of the CCF module in the PRinS are as follows.

- Selection of CCF analysis targets
- Design of the user screen for CCF analysis and input
- Retrieval and documentation of CCF analysis results

First, for screening the CCF analysis targets, the web-based CCF module is implemented to extract all target information such as “Complete Failure”, “Degraded Failure”, and “Incipient Failure” in the maintenance analysis results performed by PRinS. In addition, the CCF module links the relevant information such as equipment information, failure causes, failure time, unavailability time, and maintenance history as well as equipment maintenance analysis results. Next stages of development have added useful functions to the module for the extraction of the potential CCF events about all selected equipment failure events. The important consideration for screening potential CCFs is the query function for the analysis period of the target component. For example, if any component is inspected every 3 months, a period of 6 months before and after the failure point should be reviewed. That is, the screening period of this component is one year. The CCF module is constructed for user to confirm the type of CCF target equipment and the common cause component group (CCCG), which are modeled in the plant PSA, within a short time.

Second, the web-based CCF module is implemented for CCF analysis and input activities based on the ICDE project form. This module contains CCF factors organized and selected by ICDE criteria. A few functions are reinforced to the module in order to verify the detailed information in the failure data, retrieve a CCF analysis history, and input the selected ICDE factor information. These functions enable specific CCF analysis for the selected equipment. Figure 1 shows a CCF search and analysis screen shot for users to perform the CCF parameter analyses.

Fig.1. Detailed search and analysis screen shot of CCF Module

Finally, four factors, which become essential inputs to the CCF module, are reflected in the DB module as the codes to analyze CCF events according to the ICDE form. These four factors are a root cause to identify the most probable cause of the equipment failure, a shared factor for multiple equipment failures, a relation factor to group multiple failures, a corrective action code to prevent recurring events.

3. Development of Common Cause Failure Parameter Analysis Program (COCAP)

The common cause failure analysis for PSA (COCAP) [3] is a program that adopts the CCF parameter estimation and parametric conversion method based on Bayesian theory in NUREG/CR-5485 [2]. This program has been developed to reflect the conditions of KHNP's CCF analysis. COCAP applies Multiple Greek Letter (MGL) or Alpha Factor and can analyze common cause component groups (CCCGs) with size of 2 to 8. In addition, by aligning separate database for specific analyses, users can input and modify various DBs. The current default DB provides U.S. nuclear regulation committee (NRC) data or WCAP-16672 data. Functions of this program are largely divided into following four categories.

- Selection of CCF parameter data
- Estimation of CCF parameter distributions
- Calculation of CCF Multipliers
- Bayesian update of CCF parameters

The final CCF parameter calculation results using this program are the CCF parameter distribution information and CCF multipliers that consider "Staggered" or "Non-Staggered" test scheme in terms of both Alpha Factor and MGL methodologies. Figure 2 shows the screen shot when users conducted analyses using the Alpha Factor methodology considering the test scheme.

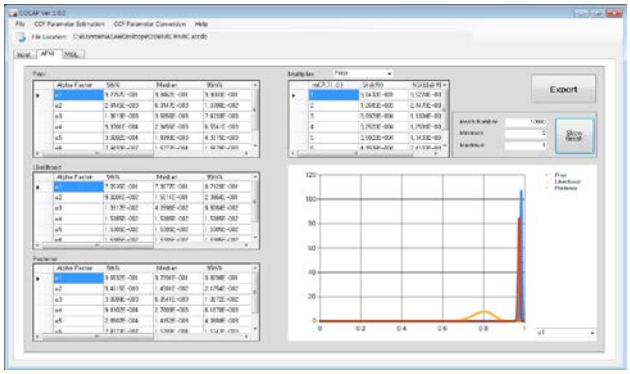

Fig.2. Screen shot of Alpha Factor method considering staggered or non-staggered test scheme

4. Conclusions

Although the portion affected by CCF in the PSA model is quite a large, the development efforts of the tools to collect and analyze data were insufficient. Currently, KHNP intends to improve PSA quality and ensure CCF data reliability by establishing a framework for plant-specific data collection and detailed analyses. In this database development activity, KHNP has built a CCF data collection and analysis module based on ICDE guidelines. This CCF database module utilizes the plant reliability DB system that is currently operated in accordance with a standard plant procedure. In conclusion, the foundation for the plant-specific CCF analysis has been established through the development of this database module program according to the major CCF parameter estimation methods.
Hereafter, the web-based CCF module, which is created by this activity, is ready to be utilized for the collection and analyses of plant-specific CCF parameters, the application of the living PSA, and the development of the reliability data book.

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