A Study on State-of-the-Art Technology for Common Cause Failures Analysis and Suggestions

Seok-Won Hwang*,a Ho-June Jeon,b Keun-Sung Lee,a Eun-Chan Lee,a
a Korea Hydro & Nuclear Power Co., Ltd. Jang-Dong 25-1, Yuseong-Gu, Daejeon, Korea, 305-343, swhwang@khnp.co.kr
b Hyundai Engineering Co., Ltd. Hyundai 41 Tower 917-9, Mok-dong, Yangcheon-Gu, Seoul, 158-723

1. Introduction

Common Cause Failures (CCFs) means the event that more than a component fails simultaneously or in similar time due to a shared cause. Two ground rules to guarantee the safety of Nuclear Power Plants are redundancy and diversity. However, the result of Probabilistic Safety Assessment (PSA) shows that CCFs contributes to the Core Damage Frequency (CDF) and system unavailability because CCFs damages the redundancy, which can defeat the redundancy employed to improve the reliability of safety functions in NPPs.

Therefore, it is necessary to correctly analyze the CCFs with an appropriate procedure because CCFs is very sensitive issue in PSA results. Therefore, it is important to estimate how CCFs affects risk. According to this, the studies on the methodology of CCFs analysis have been issued, and Risk-Informed Application (RIA) makes the studies on CCFs uncertainty more active. In this paper, state-of-the-art technology of CCFs analysis and suggestions to resolve technical problems related to CCFs for the future are provided.

2. Current Status Review of Domestic & Foreign Common Cause Failures Analysis

Most domestic CCFs analyses have been performed using Multiple Greek Letter (MGL) model. There is, however, no specific data to meet the requirement of ASME PRA Standard II[1] because the events related to CCFs occur rarely. As a result, the generic data provided in EPRI URD Rev.7[2] or NUREG Report has been used as the parameters in modeling. To resolve the lack of the data from NPPs, 11 countries are performing International CCF Data Exchange (ICDE) project organized by Nuclear Energy Agency (NEA). The purpose of the ICDE project is to allow multiple countries to collaborate and exchange CCFs data to enhance the quality of risk analyses that include CCF modeling.

Korea Atomic Energy Research Institute has participated in this project since 2002. In this project, the 11 countries exchange the information on CCFs in In-Kind way. In 2005, to provide the information on Emergency Diesel Generator (EDG) CCFs of YGN 3,4 and UCN 3,4, KAERI obtained the data on EDG CCFs from Pressurized Water Reactors (PWRs) in other countries.

In CCFs analysis, the parameters are estimated differently according to test methods of components. In domestic PSA models, the parameters, however, have been estimated with assumption that all components are tested in staggered method. Although KAERI performed the study in which the parameters were estimated considering staggered and non-staggered test scheme in PRiME model of UCN 3,4[3], this was only a beginning. There are several methods to estimate the parameters for CCFs. These methods are Basic Parameter Model, Beta Factor Model, MGL Model, and Alpha Factor Model. According to the experts' recent opinion, Alpha Factor Model is more appropriate to analyze CCFs than any others with respect to the Risk-Informed Application (RIA) and uncertainty analysis. However, the most important task is to set up the domestic specific CCFs database. For the purpose of this, the active technical co-work among each institution is required.

If a system arrangement is changed and a system is out of service, the parameters for CCFs are estimated differently. Nowadays, a few studies are being performed to resolve these problems. More studies, therefore, should be performed. Nuclear Regulatory Commission provides the information on CCFs database, analysis programs and technical documents to the industry of NPPs for performing more accurate PSA. In "General Insights from Analysis of Common Cause Failure at U.S. Nuclear Power Plants (2005)"[4] published by USNRC, the CCFs are estimated using the data from License Event Reports (LER), Nuclear Plant Reliability Data System (NPRDS) and Equipment Performance and Information Exchange (EPIX) from 1980 to 2003.

Basic information about the nature of CCFs events is displayed in Figure 1 & 2.

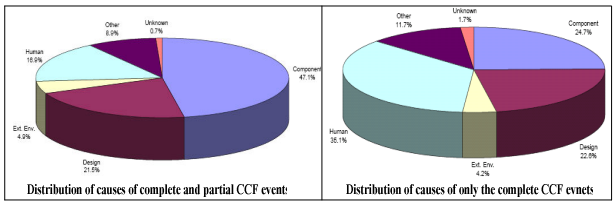

Figure 1. Distribution of CCF events by proximate cause

These figures illustrate the distribution of CCFs event proximate causes and shared cause factors, respectively. This information provides a general picture of the types of

events that may be expected to occur, and what design features might be most susceptible to CCFs events. These figures also illustrate the different characteristics of partial CCF events and complete CCFs.

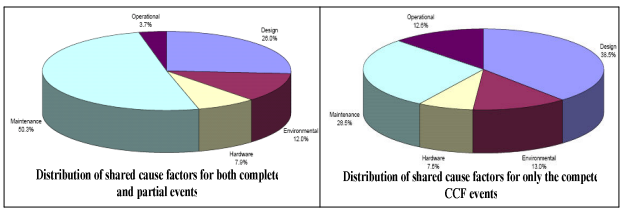

Figure 2. Distribution of CCF events by shared cause factor

With respect to quantification of CCFs, the overall conclusion, based on the evaluation of 20 years of operating data, is that CCF parameters for similar components vary among systems and failure modes.

3. Suggestions for Domestic CCF Research

3.1 Data Base of Common Cause Failures

Using Enterprise Resource Planning (ERP) system, Korea Hydro & Nuclear Power (KHNP) has collected and managed the data from NPPs since July of 2003. It is considered that the data for CCFs should be collected and managed by this system.

At present, Web-Based Plant Reliability Information System (PRinS) is being developed by using the ERP system. Hereafter, PRinS will be used in several fields. It is considered that using ERP system is the best way for managing CCFs data because a lot of data are required on Root Cause Analysis, Coupling Factor and estimating the parameters for CCFs. To manage ERP data easily for CCFs related analysis, a systematic utility program should be developed. In addition, the data from ICDE project shall be managed properly in the system.

3.2 Consideration of Impact Vector and Test Scheme

Although constructing CCFs database, the data from other NPPs should be used, because the events related to CCFs rarely occur. When using the data from other NPPs to perform CCFs analysis, impact vector should be employed. All the available sources should be identified for impact vector analysis. For multiple failure events, data from a single NPPs would not conclude a statistically meaningful result. The more information the better-quality database can be achieved. In addition, it is necessary to develop a user friendly program for qualitative and quantitative analysis (e.g., mapping up and mapping down). It is also considered that re-estimating CCFs in PSA models should be performed with applying staggered and non-staggered test scheme for the equipments related to CCFs.

3.3 Common Cause Failures Modeling

In case of system reliability analysis, it is assumed that a basic event of the models is an independent event. The operating experience of NPPs shows that the dependency from Functional, logical and other several reasons exists.

For example, HPSI pumps or LPSI pumps in KSNP provide the safety injection to 4 cold-legs in the injection mode. However, HPSI pumps only provide safety injection to both cold and hot legs in the "recirculation" mode. Because methods for CCF modeling are not established in this case, there will be many problems in the analysis. The limit against these PSA modeling has to be solved through research.

4. Conclusion

In this paper, the domestic & foreign state-of-the-arts and the latest issues for CCFs were reviewed and suggestions to resolve technical problems related to CCFs were provided. As stated above, CCFs are major contributors to system unavailability and CDF because they can defeat redundancy of NPPs. Therefore it is very important not only to estimate the potential and the probability of CCFs but also to prepare an improvement program. In the long-term, the construction of domestic specific database is desired. This is also considered important to the aspects of improving PSA quality. Considering domestic technical condition for CCFs, it is difficult to resolve technical problems in the short time.

Thus, all of the business owner, the regulatory institute, the research and the academic institute should try to resolve these problems.

REFERENCES

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[3] “Guidelines for System Modeling: Common Cause Failures (Rev.1),” KAERI, KAERI/TR-2916/2005, January, 2005.

[4] “General Insights from Analysis of Common-Cause Failure Data at U.S. Nuclear Power Plants,” USNRC, October, 2005.