Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Common Cause Failure Analysis Calculator for Parameter Estimations

Daeil Kang[a], Sang Hoon Han[a], Mee Jung Hwang[a], and Sang Hyeon Park[b]
[a]*Korea Atomic Energy Research Institute,150 Deogjin-Dong, Yuseong-Gu, Daejeon, 305-353,dikang@kaeri.re.kr*
[b]*ENERSYS,* Third Floor, Pianetta Bldg., 337-2, Jangdae-dong, Yuseong-gu, Daejeon, 305-308

1. Introduction

Detailed common cause failure (CCF) analysis is required for an improvement of the PSA quality and for a reasonable quantification of the CCF probability. However, it generally needs the data for CCF events of other nuclear power plants because these CCF events rarely occur. To get the data for the CCF events [1], KAERI has been participating in the international common cause failure data exchange (ICDE) project. ICDE project is being operated by OECD/NEA and its purpose is to internationally collect and analyze CCF events. As there was no computerized tool for an estimation of the CCF parameters with the ICDE data, KAERI developed a CCF analysis calculator. In this paper, the estimation procedure of the CCF parameters [2] and the developed computer program are presented.

2. Estimation Procedure of CCF Parameters

The estimation procedure of the Alpha factor used in this study follows the approach of the NUREG/CR-5485[3]. Each CCF event in the ICDE database is represented by the impact factors to classify events according to the level of impact of CCF events [1]. It has three impact vectors: component impairment, shared cause factor, and time factor.

First, common cause component group (CCCG) components of the target plant are determined and the number of independent failure events and CCF events is identified. Next, generic impact vectors of the CCF event are calculated through considering three impact vectors. Then, the qualitative and quantitative differences between the original system and the target systems are adjusted by multiplying the generic impact vector by an event applicability factor and by mapping the original to the target system, respectively. The event applicability factor for each CCF event in the ICDE database is estimated based on the characteristics (design, operation, cause defense, coupling defense, etc) of the CCCG components for a target plant. Then, the number of events in each impact category is estimated by adding the corresponding elements of the impact vector. Then, the Alpha factor priors are estimated. With the failure data of CCCG components of target plant, the Alpha factor likelihood is estimated. And, the Bayesian updating for the estimation of the Alpha Factors is performed. Finally, CCF factors and MGL parameters are estimated with the estimated Alpha factors.

The mean value of the Alpha parameters is calculated by using the following Eq. (1)

$$\text{mean}(\alpha_k) = A_k/A_T = a/(a+b) \quad (1)$$

where, $A_T = \sum_{k=1}^{m} A_k$

$a = A_k$, $b = A_T - A_k$, k=1, 2, 3, 4,……
$A_k = P_k + S_k$, k=1, 2, 3, 4,……
$S_K = S_{0K}$, $P_K = P_{0K}$, k= 2,3,4,…
$S_1 = S_{01} + IN_S$, $P_1 = P_{01} + IN_P$, k= 1
S_{0K} = number of CCF events involving k specific components for target plant
P_{0K} = number of CCF events involving k specific components for ICDE DB
IN_S =number of independent events for target plant
IN_p=sum of number of adjusted ICDE independent event

The probability of a CCF event involving *k* specific components in a CCCG of size *m* for a staggered testing scheme, $Q_k^{(m)}$, is calculated by using the following equation[2,3]:

$$Q_k^{(m)} = (\alpha_k^{(m)} / {}_{m-1}C_{k-1}) * Q_t \quad .(2)$$

where, Q_t = total failure probability of a component in a CCCG due to all independent and common cause event

From Eq.(2), CCF factors are defined as $(\alpha_k^{(m)} / {}_{m-1}C_{k-1})$. MGL parameters are defined as bellows:

$$\beta = \sum_{k=1}^{m} \alpha_{k+1}, \quad (3)$$

$$\rho_{j+2} = \sum_{j=1}^{m} \left(\sum_{k=1}^{m} \alpha_{k+j+1} / \sum_{k=1}^{m} \alpha_{k+j} \right) \quad (4)$$

$\rho_1 = 1$, $\rho_2 = \beta$, $\rho_3 = \gamma$, $\rho_4 = \delta$, $\rho_5 = \varepsilon$, $\rho_6 = \mu$, $\rho_7 = \upsilon$, $\rho_8 = \kappa$,

For the case of non-staggered testing, CCF factors and MGL parameters are presented in reference [2]

3. CCF Analysis Calculator

The CCF analysis calculator was programmed by Microsoft Visual Basic 2005 and .NET. The developed program consists of the CCF event data base, called "Review of ICDE DB" and the CCF parameter calculator, called "Calculations of CCF parameters." In the "Review of ICDE DB," the CCF data of the ICDE DB can be searched and reviewed. The data base structure of "Review of ICDE DB" is almost the same as the SUSI-Q, data base program of the ICDE CCF events.

In the "Calculation of CCF parameters," applicability factors of each CCF event in the ICDE DB, Alpha factors, CCF factors, and MGL parameters are estimated. Figure 1 and 2 show the process for calculating applicability factors and the estimated results of the Alpha factors, respectively.

4. Concluding Remarks

In this paper, the developed CCF parameter calculator with its estimation process is presented. The use of the CCF analysis calculator will contribute to an improvement of the PSA quality for the domestic NPPs and will yield reasonable quantification results of a CCF probability. As a future study, the function for performing parameter uncertainty analysis will be added to it. Also, a refinement of the Bayesian update approach will be pursued.

Acknowledgements

This work has been carried out under the Nuclear R&D Program by Ministry of Science and Technology of Korea.

References

[1]. OECD Nuclear Energy Agency, International Common-cause Failure Data Exchange, ICDE General Coding Guidelines, NEA/CSNI/R(2004)4, January 2004
[2]. Kang, Daeil, Procedure of Calculation for CCF Parameters, unpublished presentation material, 2007
[3]. U.S. NRC, Guidelines on Modeling Common-Cause Failures in Probabilistic Risk Assessment, NUREG/CR-5485, Nov. 1998..

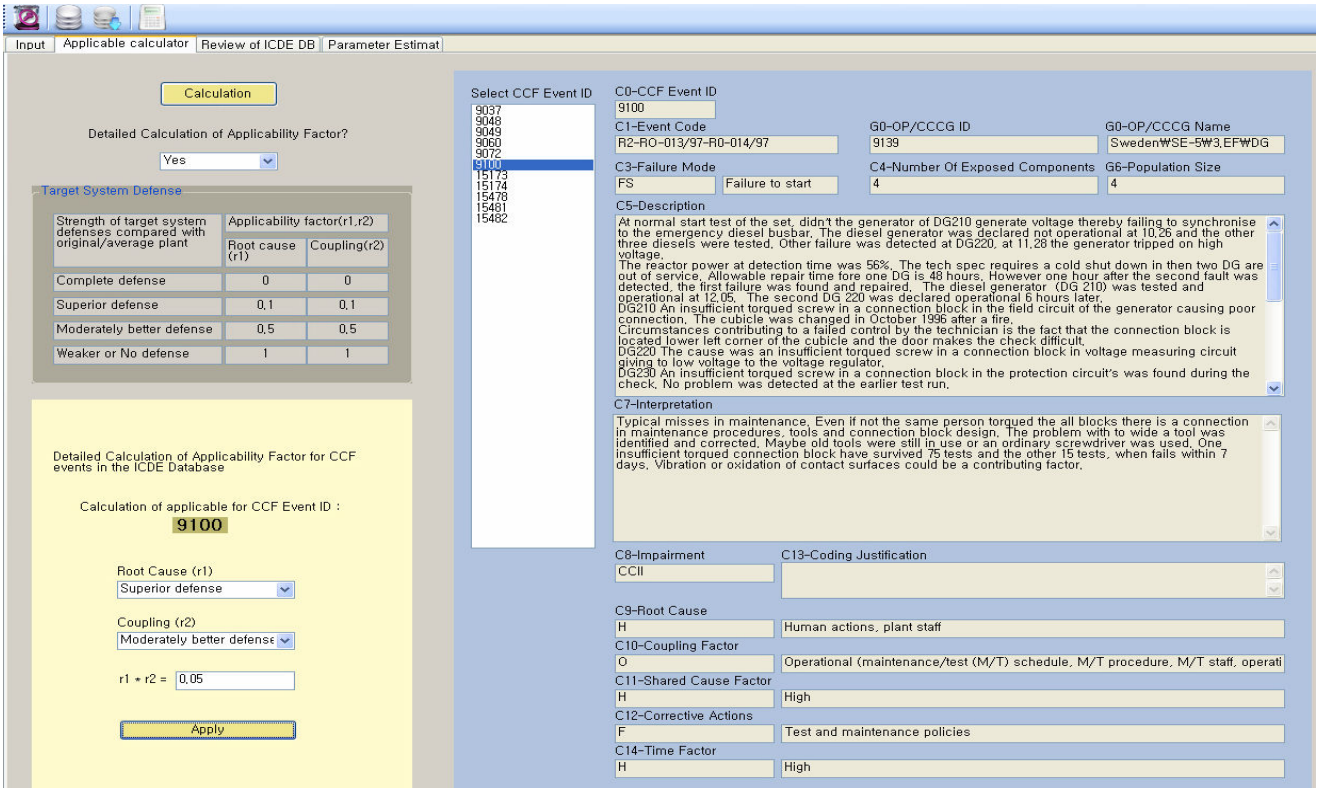

Figure 1. Process for calculating applicability factors

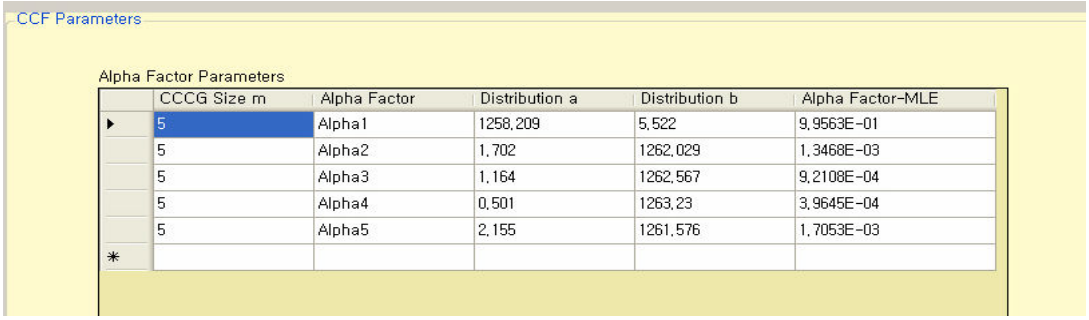

Figure 2. Estimated results of Alpha factors