Re-estimation of the Alpha Factor Parameters for the Emergency Diesel Generators of Ulchin Unit 3

Dae Il Kang and Sang Hoon Han
Korea Atomic Energy Research Institute,150 Deogjin-Dong,
Yuseong-Gu, Daejeon, 305-353, dikang@kaeri.re.kr

1. Introduction

Common cause failure (CCF) event is defined as a dependent failure event in which two or more component fault states exist simultaneously, or within a short time interval, and are a direct result of a shared cause [1,2,3]. As the plant specific CCF events are rare, parameter estimation for the CCF analysis have to rely mostly on experience data from other nuclear power plants (NPPs). The OECD/NEA initiated the International Common-Cause Failure Data Exchange (ICDE) Project to collect and to analysis CCF events [1]. Korea has participated in the ICDE Project since 2002.

In the previous study[4], we estimated the Alpha factor parameters for the Ulchin Unit 3 emergency diesel generators (EDGs) by using the ICDE data. The applicability factor had been assumed to be 1. However, a detailed review of the ICDE data shows that some CCF events can be screened out. Thus, we re-estimated the Alpha factor parameters for the Ulchin Unit 3 emergency diesel generators (EDGs) by using the ICDE data. The estimation procedure of the Alpha factor used in this study follows the approach of the NUREG/CR-5485[3].

2. Method for Alpha Factor parameter estimation

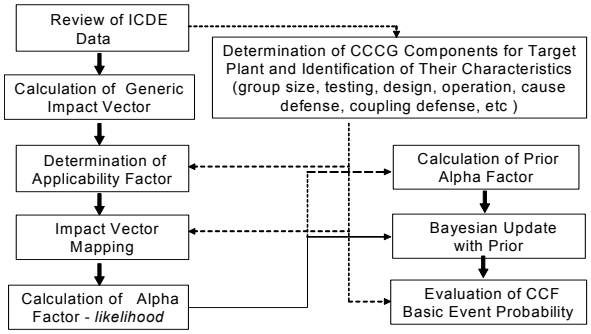

Figure 1. Estimation procedure of Alpha Factor parameters

Figure 1 shows the estimation procedure of the Alpha factor parameters by using the ICDE database performed in this study. First, qualitative and quantitative information for the CCF analysis was identified through reviewing the ICDE data. After that, common cause component group (CCCG) components of the target plant were determined and their defenses for the previous CCF events of the original plant in the ICDE database were identified. Thirdly, generic impact vectors of the CCF event were calculated through considering three impact vectors. Fourthly, the qualitative and quantitative differences between the original system and the target systems were adjusted by multiplying the generic impact vector by an event applicability factor and by mapping the original to the target system, respectively. Fifthly, the number of events in each impact category was calculated by adding the corresponding elements of the impact vector. And, the Alpha factors were estimated. Finally, the Bayesian updating was performed.

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

$a = A_k$

$b = A_T - A_k$

$A_k = A_{0k} + N_k$

$A_{0k} = a_0$ of Prior distribution

$N_1 = IN + n_1$ for k=1

$N_k = n_k$ for k=2,3, & 4

IN: the number of 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]:

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

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

3. Application Results

Ulchin Unit 3 has two EDGs. The alternate AC (AAC) is shared with four NPPs, but it can be connected to only one NPP. Except the AAC, there is no cross linking between the EDGs or the Class 1E buses of each NPP. Following assumptions were made in the estimation of the Alphar factor parameters of the EDGs for Ulchin Unit 3:

- For the cases where the component impairment status of all the components in the CCCG of the ICDE database is identified as “complete”, the CCF events

were assumed to be the "lethal events". The other CCF events were to be "non-lethal events".

- Generic impact factors were calculated without any change of the original impact factors for the CCF events in the ICDE database.
- For two EDGs of Ulchin Unit 3, the applicability factor of each CCF event in the ICDE Database was assumed to be 1. However, for three EDGs including the AAC, the applicability factors of the CCF events in Table 1 were assumed to be 0.5.
- The EDG and AAC were manufactured by the same company, but their supporting systems were designed differently. As the supporting systems were separately modeled in each diesel generator, we assumed them to be the same CCCG.

From the basic assumptions and eq.2), the unavailability equation of an EDG is represented as follows:

$Q(\text{ for EDG A, or B}) = Q_1+Q_2+Q'_2+Q_3$ ……....(3)

$Q(\text{ forAAC}) = Q_1+2Q_2+Q_3$ ……...(4)

where,

$$Q_1 = \alpha_1 * Q_t \approx Q_t,$$
$$Q_2 = (\alpha_2 / 2) * Q_t \quad \text{……(5)}$$
$$Q'_2 = (\alpha'_2 / 2) * Q_t$$
$$Q_3 = \alpha_3 * Q_t$$

Based on the method and assumptions mentioned above, we estimated the alpha factors of the EDGs for Ulchin Unit 3 by using the ICDE Database. As presented in Eq.(1), the Alpha factor parameters are dependent on not only the number of CCF events but also the number of independent cause failure events. If some CCF events in the ICDE Database can be excluded, the corresponding independent cause failure events related to them should also be excluded. However, information for the independent events in the ICDE Database is not presented. Thus, without changing the number of the independent cause failure events, we assumed that the applicability factors for the CCF events mentioned above were 0.5. Tables 2 and 3 shows the estimated Alpha parameters for "fails to start" and "fails to run", respectively. The estimated Alpha parameters are lower than those of the previous study.

4. Conclusions

In this study, we re-estimated the Alpha parameters of the EDGs for Ulchin Unit 3 by using the ICDE Database. The CCF events related to the supporting systems and signal generations were identified that they could be screened out. However, information for the independent events in the ICDE Database is not presented. Thus, without changing the number of the independent cause failure events, we assumed that the applicability factors for the CCF events which can be excluded were 0.5. The study results show that the estimated Alpha factor parameters are lower than those of the previous study. Further studies are needed for an establishment of the procedure for an assessment of the applicability factor when detailed information of the independent cause failure events is unavailable.

Table 1. CCF events not applicable to two EDGs and AAC

Failure types	CCCG ID	Reasons for exclusion
Fails to run	9111	Cooling system related
	9146	Cooling system related
Fails to start	9073	Signal related – single button disabled two EDGs
	9146	Signal related
	9185	Signal related

Table 2. Estimated Alpha factors for " fail to start"

Alpha factors	Exclusive CCF events: AF*-0.5, Other CCF events: AF*-1	All CCF events:AF*-1	NUREG/ CR-5497
α_1	9.79E-1	9.78E-1	9.63E-1
α_2	1.0E-2	1.01E-2	2.04E-2
α'_2	1.01E-2		
α_3	1.04E-2	1.20E-2	1.66E-2

*: applicability factor

Table 3. Estimated Alpha factors for " fail to run"

Alpha factors	Exclusive CCF events: AF*-0.5, Other CCF events: AF*-1	All CCF events:AF*-1	NUREG/ CR-5497
α_1	9.82E-1	9.81E-1	9.508E-1
α_2	8.39E-3	8.50E-3	2.89E-2
α'_2	8.50E-3		
α_3	9.39E-3	1.02E-2	2.11E-2

*: applicability factor

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]. Mee-Jung Hwang et al., Guidance for Common Cause Failure Analysis, KAERI/TR-2444/2003, KAERI, 2003

[3]. U.S. NRC, Guidelines on Modeling Common-Cause Failures in Probabilistic Risk Assessment, NUREG/CR-5485, Nov. 1998.

[4]. Kang, D.I et al., Estimation of Alpha Factor Parameters for Emergency Diesel Generator, 2005 KNS Autumn meeting, 2005

[5]. U.S. NRC, Common-Cause Failure Parameter Estimations, NUREG/CR-5497, 1998