Estimation of Alpha Factor Parameters for Emergency Diesel Generator

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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 at the ICDE Project from year 2002.

The Alpha Factor model was chosen for the CCF analysis of the PSA model for the Korea Standard Nuclear Power Plant (KSNP) [4]. However, the generic values [4, 5] of the Alpha Factor were used in it. We estimated the Alpha Factor parameters for the KSNP emergency diesel generator (EDG) through the plant specific CCF parameter estimation using the ICDE data. The objectives of this study are to improve the quality in the field of CCF analysis of the PSA model for the KSNP and to establish the procedure of CCF parameter estimation using the ICDE data.

2. Method for Alpha Factor parameter estimation

Figure 1 shows the estimation procedure of Alpha Factor parameters performed in this study. The Bayesian update with prior was not carried out.

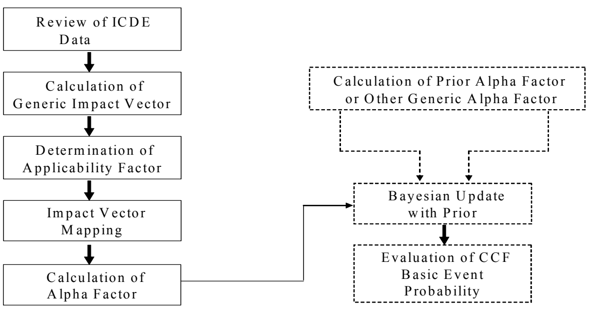

Figure 1. Estimation procedure of Alpha Factor parameters

2.1 Calculation of impact vector

Each CCF event in the ICDE database is represented by the impact factors to classify events according to the level of impact of CCF [1]. Each CCF event in the ICDE database has three impact vectors: component impairment, shared cause factor, and time factor [1]. Each participant of the ICDE project record the coding for the impact vectors according to the ICDE guidelines.

Generic impact factor of the CCF event is calculated through considering three impact vectors mentioned above. Modification to the original impact vector for application to plant specific analyses requires a two-step adjustment of the original impact vector to account for qualitative and quantitative differences between the target (the KSNP) and original (the ICDE) systems [2, 3, 4]. The qualitative adjustment can be performed through multiplying the calculated generic impact vector with applicability factors which are measures of applicability of a CCF event to the target system. The quantitative adjustment is performed by mapping-up or mapping-down.

2.2 Estimation of Alpha Factor

The parameters of the alpha-factor model can be estimated using the following maximum likelihood estimators (MLE) [2, 3, 4]:

$$\alpha_k^{(m)} = n_k / (\sum_{i=1}^{m} n_i) \quad \text{.........................(1)}$$

where,

$\alpha_k^{(m)}$ = fraction of the total frequency of failure events that occur in the system and involve the failure of k components due to a common cause

n_j = the sum of the *jth* element of the impact vector, over all events

n_1= sum of the first element and the adjusted independent events

adjusted independent events = (independent event count * mapped common-cause component group (CCCG))/original CCCG

2.3 Evaluation of CCF basic event probability

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 using following equation [2, 3, 4]:

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

where,

Q_t = total failure probability of a component in a

CCCG due to all independent and common cause event

3. Application Results

One NPP of the KSNP has two EDGs. The alternate AC (AAC) is shared with six NPPs, but it can be connected to only one NPP. Except the AAC, there is no any cross link between the EDGs or the Class 1E buses of each NPP. Following assumptions were made in the estimation of Alphar Factor parameters for the KSNP EDG:

1) For the cases where the component impairment status of all 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".

2) Generic impact factors were calculated without any change of original impact factors for the CCF events in the ICDE database. As we did not find any qualitative difference between the target system and the original systems, the applicability factor of each CCF event was assumed to be 1.

3) The EDG and AAC are manufactured by the same company, but their supporting systems are differently designed. As the supporting systems were separately modeled in each diesel generator, we assumed them as the same CCCG.

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

$Q(\text{ for EDG A, B, or AAC}) = Q_1+2Q_2 + Q_3$ ……...(3)

where,

$Q_1 = \alpha_1 * Q_t \approx Q_t$,
$Q_2 = (\alpha_2 / 2) * Q_t$ ……………………….(4)
$Q_3 = \alpha_3 * Q_t$

Based on the method and assumptions mentioned above, we estimated the alpha factors for the KSNP EDG using the ICDE datae. The estimation results for the alpha factors are presented in Table 1. The calculated probability of a CCF event involving *k* specific components using the ICDE data is presented in Table 2. With the CCF basic event probability of the ICDE in Table 2, the EDG system unavailability of the 1 out of 3 success criterion is calculated as 2.96E-3. With that of the NUREG/CR-5497 [5], it is calculated as 4.15E-3.

4. Conclusions

Up to the present, the generic values of the CCF event parameters have been used in most PSA projects for the Korean NPPs. The ASME PRA Standard [6] requires that the CCF analysis be performed with plant specific information. We estimated the Alpha Factor parameters for the KSNP emergency diesel generator (EDG) through the plant specific CCF parameter estimation using the ICDE data. The study results show that the estimated alpha parameters using the ICDE data are lower than those using the generic values of the NUREG/CR-5497. If the Bayesian update with prior is performed, the alpha parameters is slightly higher than those calculated in this study. For more active plant specialization of the ICDE data to the domestic NPPs, it is suggested that the following studies be performed: the collections and analyses of the CCF events for all domestic NPPs, and the computerization of the CCF parameter estimation procedure using the ICDE data.

Table 1. Estimated alpha factor for the KSNP EDG

Alpha Factor	CCCG=2		CCCG=3	
	Fail to start	Fail to run	Fail to start	Fail to run
α_1	0.9785	0.9791	0.9784	0.9821
α_2	2.15E-2	2.09E-2	9.8E-3	8.09E-3
α_3			1.12E-2	1.66E-2

Table 2. Calculated CCF Probability using the ICDE data and the generic values of NUREG/CR-5497

Databases	Q_2		Q_3	
	Fail to start	Fail to run	Fail to start	Fail to run
ICDE	2.2E-4	2.33E-4	5.29E-4	5.63E-4
NUREG/ CR-5497	4.58E-4	8.29E-4	7.543E-4	1.22E-3

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