An Estimation of Generic CCF Parameters by Using the ICDE Data

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1. Introduction

In this paper, we present an estimation result of generic Common Cause Failure (CCF) parameters by using International CCF Data Exchange (ICDE) data.
Because the CCF events are very rare, CCF event data of other plants are generally necessary for the detail analysis of CCF in Probabilistic Safety Assessment (PSA). Thus, for obtaining the CCF event raw data, KAERI has been participating in the ICDE (international common cause failure data exchange) project since 2002. KAERI obtained about 400 CCF event data for emergency diesel generators, motor operated valves, check valves, pumps, and breakers from the operation agency of the ICDE project in 2009.
With CAFE-PSA (common CAuse Failure Event analysis program for PSA) which is developed in KAERI to estimate CCF parameters, we analyzed qualitatively and quantitatively the ICDE CCF events. In a qualitative analysis, root causes, coupling factors, corrective actions, and detection methods of CCF events were analyzed according to their component types, sub-component types, and countries. In a quantitative analysis, CCF parameters of components for staggered testing strategies were analyzed for two trains.

2. Estimation of Generic CCF Parameters

With CAFÉ–PSA, KAERI performed the pilot quantification the quantitative analysis for 8 cases (CV-all type, MOV-all type, EDG, AFWS-all type, ESWS PP, HPSI PP, CSS PP, CCWS PP). Generic prior data of NRC-2007 was used in the analysis of ICDE as the prior.
Figure 1 shows the procedure of CCF parameter estimation by using CAFÉ-PSA.

2.1 Quantitative Analysis

In case of using ICDE DB as input, qualitative analysis procedures are as follows:

- Selection of a component
- Selection of component type
- Selection of country
- Analysis

For the selected components events, root cause, coupling factor, corrective action, and detection method are analyzed.

Table 1 presents the results of qualitative analysis for an emergency diesel generator. According to the root cause analysis result in Table 1, the number of events due to a harsh environment is 7 of total 68 events, and the ratio is 10.29%. The highest ratio is 52.94%, 36 design defect (D) events. Total number of CCF events in detection method (C6) is 72 because detection method is double-counted.

Table 1. The Result of Qualitative Analysis for Emergency Diesel Generator

Root Cause (C9)									
Section	A	C	D	H	I	M	O	P	Total
No. of events	7	1	36	6	4	3	1	10	68
Percentage[%]	10.294	1.471	52.94	8.824	5.882	4.412	1.471	14.7	
Coupling factor (C10)									
Section	E	H	HC	HQ	HS	OMP	OMS	O	Total
No. of events	5	28	10	1	5	7	1	11	68
Percentage[%]	7.353	41.176	14.71	1.471	7.353	10.294	1.471	16.2	
Corrective actions (C12)									
Section	A	B	C	D	E	F	G	O	Total
No. of events	15	5	12	10	7	9	2	8	68
Percentage[%]	22.059	7.353	17.65	14.71	10.29	13.235	2.941	11.8	
Detection method (C6)									
Section	Empty	MA	MC	MW	TA	TI	TU	Total	
No. of events	40	10	1	4	1	14	2	72	
Percentage[%]	55.556	13.889	1.389	5.556	1.389	19.444	2.778		

2.2 Quantitative Analysis

In CAFÉ-PSA, one stage Bayesian method is used to estimate CCF parameters. Figure 1 shows the procedure of CCF parameter estimation by using CAFÉ-PSA.
For estimation of CCF parameters by using ICDS data, the prior distribution in US NRC 2007 CCF parameter estimation is used as the prior distribution, ICDE CCF events data are used as the likelihood. In this analysis, alpha-factor for the 2-train system is only estimated. Applicability factor is assumed as 1 for all cases. In the case that the number of exposed components (C4) and impairment vector (C8) are same, and all of component damage vector and all of the shared cause and the time factor are estimated as C and high, respectively, it is regarded as a lethal shock.
In Table 1, alpha factor estimation result for the 2-train system by using ICDE data is compared as the NRC alpha factor. In this alpha factor estimation, it is assumed that the staggered test for components is performed. NRC-2007 means the NRC data on website. The analysis result of the US data from 1990 to 2007. ‘n/a’ means that there is no independent failure event.

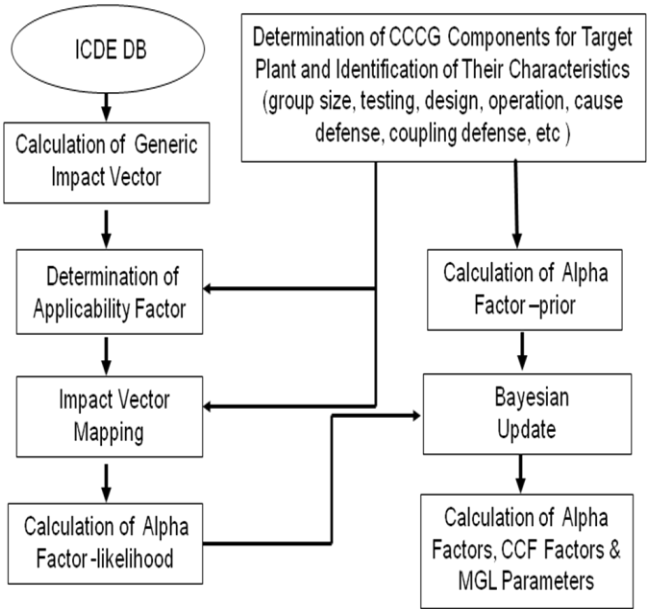

Figure 1. The Procedure of CCF parameters estimation by using CAFE-PSA

Table 2. The Results of ICDE Alpha Factor Estimation for the 2train System

Component	Failure Mode	ICDE	NUREG/CR-5497(1998)	NRC-2007*
CV-all type	FO	9.86E-02	n/a	1.38E-02
MOV-all type	FO	3.26E-02	n/a	2.28E-02
EDG	FR	1.97E-02	4.02e-2	1.55E-02
	FS	2.02E-02	3.14e-2	1.15E-02
AFWS-all type	FR	1.54E-02	1.88e-2	n/a
	FS	2.55E-02	1.11e-2	n/a
ESWS PP	FR	4.12E-02	0.0384**	0.0126**
	FS	3.62E-02	0.0367**	0.0155**
HPSI PP	FR	5.06E-02	2.20e-2	3.07E-02
	FS	4.50E-02	5.51e-2	1.86E-02
CSS PP	FR	1.81E-02	n/a	1.25E-02
	FS	7.47E-02	n/a	4.17E-02
CCWS PP	FR	8.13E-03	n/a	8.38E-03
	FS	7.07E-02	n/a	5.48E-03

FO: fails to open, FC: fails to close, FR: fails to run, FS: fails to start

* NRC-2007: NRC data on website. The analysis result of the US data from 1990 to 2007.

**It's not identified whether the strainer and traveling screen are included in the pump data or not.

3. Results

The qualitative analysis results of the ICDE CCF data, by using the CAFE-PSA, showed that the major root cause of CCF events, for motor operated valves, check valves, and pumps, was the fault of their internal parts, and that for emergency diesel generators and breakers was the inadequacy of design/manufacture or construction. The quantitative analysis results of the ICDE CCF data, by using the CAFE-PSA, showed that the estimated alpha factors of components, mentioned above, were lower than those previously used in the PSA for domestic nuclear power plants, but were higher than those in USNRC 2007 CCF data.

4. Conclusions

Through performing qualitative and quantitative analysis of the ICDE CCF data, by using the CAFE-PSA, a plan for coping with CCF events for design and operation of nuclear power plants can be produced, and reasonable values for CCF parameters can be estimated. In addition, it is expected that the technical adequacy of PSA can be improved.

Acknowledgments
This research was supported by "The Mid-&-Long Term Nuclear R&D Program" of MEST (Ministry of Education, Science and Technology), Korea.

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