

# 가 A Study of Calculation Method for RAW including CCF

150

가 (RAW) 가  
 , RAW가 가  
 가  
 , 가  
 RAW  
 RAW

## Abstract

In this paper, a new calculation method to derive a component RAW using failure mode event RAW including CCF (Common Cause Failure) is suggested and compared with the U.S. industry method. Since the new method suggested in this paper approaches a real RAW value in a little bit conservative manners in the probabilistic safety assessment models of real nuclear power plants, it can be very useful in the calculation of the group RAW which plays a key role in the risk informed regulation and applications.

### 1.

(Risk Informed Regulation & Applications: RIR&A) / /  
 (Structures, Systems, Components: SSC) SSC SSC  
 Vesely (FV) 가 (Risk Achievement Worth: RAW) Fussell-<sup>1</sup>  
 RIR&A 가 (Graded Quality Assurance: GQA)<sup>2</sup> Option 2<sup>3</sup> 가 . GQA  
 (RISC-3 ) QA . , GQA Option  
 2 RISC-3 ( , QA,  
 , , , ..) . RISC-3  
 FV RAW .  
 , GQA Option 2 가 , FV  
 RAW / 가(PSA) FV  
 RAW FV RAW FV RAW  
 FV RAW (Common Cause Failure: CCF)

RAW 4.

1997 가 South Texas 4, GQA CCF RAW  
 South Texas RAW, GQA Option  
 2 가 RAW, CCF 가 Option 2 South Texas GQA  
 , RISC-3 RAW 가 RISC-3 가 Option 2  
 NEI-00-04 5,6 NEI NEI

, South Texas GQA RAW  
 ACRS NEI가 NRC  
 Option 2, CCF RAW  
 , NEI가 CCF RAW

## 2. NEI

NEI 6 Option 2 1  
 FV FV RAW CCF  
 RAW RAW CCF RAW  
 , RAW>20 6  
 1. 6

Component Failure Mode	FV	RAW	CCF RAW
1) Valve 'A' Fails to Open	0.002	1.7	n/a
2) Valve 'A' Fails to Remain Closed	0.00002	1.1	n/a
3) Valve 'A' In Maintenance	0.0035	1.7	n/a
4) Common Cause Failure of Valves 'A' & 'B' & 'C' to Open	0.004	n/a	54
5) Common Cause Failure of Valves 'A' & 'B' to Open	0.0007	n/a	5.6
6) Common Cause Failure of Valves 'A' & 'C' to Open	0.0006	n/a	4.9
<b>Component Importance</b>	0.0108 (sum)	1.7 (max)	54 (max)
<b>Criteria</b>	>0.005	>2	>20
<b>Candidate Safety Significant ?</b>	Yes	No	Yes

1 FV CCF FV FV  
 , FV 0.0108 (= 0.002 + 0.00002 + 0.0035 + 0.004 + 0.0007 + 0.0006 )  
 0.005 RAW RAW CCF  
 RAW ( , 1.7) RAW가 1.7

RAW 2 CCF RAW RAW CCF RAW 가 ( , 54), 20 .

South Texas가 GQA 가 RAW RAW CCF RAW RAW CCF RAW RAW CCF가 RAW , CCF RAW RAW CCF가 RAW , CCF가 가 가 CCF CCF RAW가 RAW RAW RAW RAW , RAW , CCF NEI CCF RAW RAW RAW , CCF RAW , NRC (ACRS) RAW 'RAW>2' 'RAW>20' RAW 가

4. South Texas가 GQA 가 1 RAW 54 RISC-3 가 .

3.

( , (CDF)) R , base Ro , i Ri+ Ri- 가 Ri event P

$R = aP + b$  ----- (1)

, P=  
 a = P  
 b = P

R Binary Decision Diagram(BBD) Shannon Decomposition 7,8

$R = P \cdot R^+ + (1 - P) \cdot R^-$  ----- (2)

(2) (1) (2)가 (2) R , RAW FV

$RAW = 1 + FV \cdot (1 - P) / P$  ----- (3)

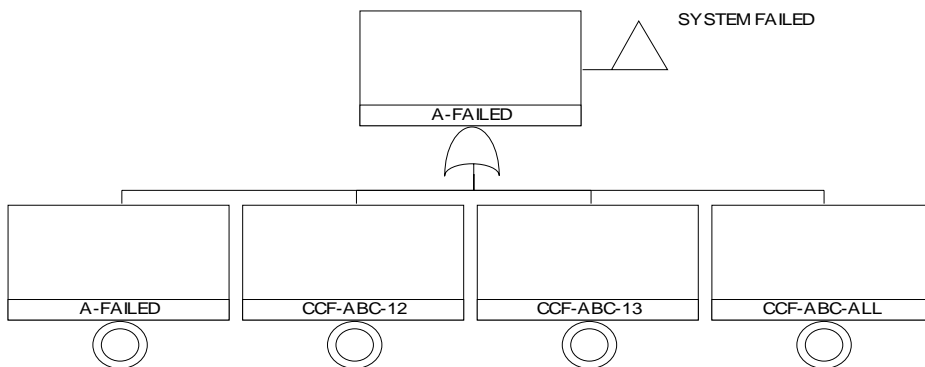
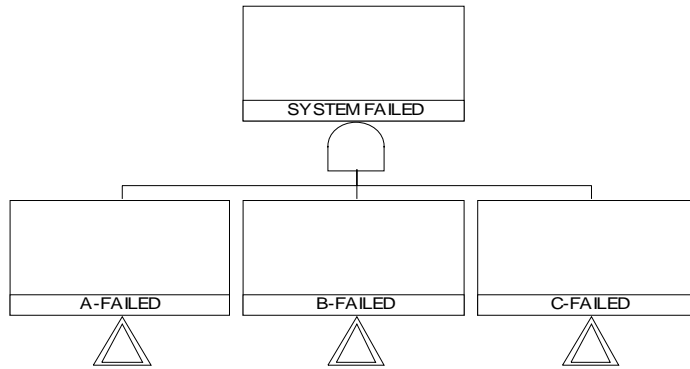
FV (3) RAW RAW P , FV (3) FV가 가 , 가 FV가 가 FV FV FV (3) FV가 가 RAW 가 .

# 4. NEI

10 NEI . 1

1

가 . A, B, C , 1 가  
 . , A 1  
 . B, C A  
 . , 2  
 A , RAW , RAW A가  
 , A가 , 3



1.

2.

Mean unavailability = 3.105E-004

```

=====
No.   Unavail.           Minimal Cutset Events
=====
1     3.000E-004    96.6   CCF-ABC-ALL
2     3.150E-006     1.0   A-FAILED      CCF-ABC-23
3     3.150E-006     1.0   B-FAILED      CCF-ABC-13
4     3.150E-006     1.0   C-FAILED      CCF-ABC-12
5     7.290E-007     0.2   A-FAILED      B-FAILED      C-FAILED
6     1.225E-007     0.0   CCF-ABC-13    CCF-ABC-23
7     1.225E-007     0.0   CCF-ABC-12    CCF-ABC-13
8     1.225E-007     0.0   CCF-ABC-12    CCF-ABC-23
=====

```

3. A가 가

Mean unavailability = 1.081E-003

```

=====
No.   Unavail.           Minimal Cutset Events
=====
1     1.000E-003    92.5   CCF-BC-ALL
2     8.100E-005     7.5   B-FAILED2    C-FAILED2
=====

```

, A RAW .

$$RAW_A = ( \text{A가} ) \div ( \text{ } )$$

$$= 1.081e-03 \div 3.105e-4 = 3.48.$$

, A RAW FV 2 4 .

$$4 \quad A \quad A \quad RAW \quad FV \quad FV$$

$$RAW(A-random) = (3E-4 + 0.00039 + 3.15E-6 \times 2 + 0.009 \times 0.009 + 1.225E-7 \times 3) / 3.105E-4 = 2.5$$

$$FV(A-random) = (3.15E-6 + 7.29E-7) / 3.105E-4 = 0.0125$$

A FV A FV .

$$A (FV) = 0.0125 + 0.01054 \times 2 + 0.966 = 0.99958$$

, A RAW 3가 .

1 : CCF 가 , A RAW . (South Texas GQA )

→ ( 4 ) 3220 ( 가)

2 : CCF , A RAW . (NEI )  
 → ( 4 ) 2.5 ( 가)

3 : A P RAW = 1 + FV\*(1-P)/P . ( )  
 → P = 0.009 + 0.00039 \* 2 + 0.0003 = 0.01 ( 4 2 )  
 → RAW = 1 + 0.99958\*(1-0.01)/0.01 ≅ 100 ( 가 ) ( 4 4 )

3 (3) RAW가 가 .

1 , RAW 3.48 , RAW  
 , South Texas GQA 가 3,220 가  
 , NEI RAW 2가 100 가 , CCF RAW  
 ( ( 2.5), CCF RAW  
 ( , 10 , 3,220).  
 , NEI 가 CCF RAW ,  
 2 ( RAW CCF ), 가 RAW CCF  
 RAW RAW , South Texas  
 GQA 가 RAW RAW 가 ,  
 , CCF ,  
 1 PSA 가 CCF RAW ,  
 , PSA ,  
 , RAW 가 .

4. RAW FV

Event	P	FV	RAW
A - random	0.009	0.0125	2.5
B - random	0.009	0.0125	2.5
C - random	0.009	0.0125	2.5
CCF - ABC - 12	0.00039	0.01054	31
CCF - ABC - 13	0.00039	0.01054	31
CCF - ABD - 23	0.00039	0.01054	31
CCD - ABC - all	0.0003	0.966	3220
A - Component	0.01	0.99958	100

3 (LPSI) RAW 5  
P, FV, RAW 11.

5. FV, RAW<sup>11</sup>

Basic Event	Description	P	FV	RAW
LSMPKLPSIP	CCF(RUNNING) OF LPSI PUMPS (2/2)CCF	1.92E-05	0.0004	21.8322
LSMPMLPSI1	LPSI PUMP 1 UNAVAILABLE DUE TO MAINTENANCE	1.76E-03	0.0003	1.1687
LSMPMLPSI2	LPSI PUMP 2 UNAVAILABLE DUE TO MAINTENANCE	1.76E-03	0.0005	1.2773
LSMPRLPSI1	LPSI PUMP 1 FAILS TO RUN	2.40E-04	0	1.1607
LSMPRLPSI2	LPSIPUMP 2 FAILS TO RUN	2.40E-04	0	1.1764
LSMPSLPSI1	LPSI PUMP 1 FAILS TO START	2.30E-03	0.0005	1.2054
LSMPSLPSI2	LPSI PUMP 2 FAILS TO START	2.30E-03	0.0007	1.314
LSMPWLPSIP	CCF(DEMAND) OF LPSI PUMPS	1.36E-04	0.0029	22.1099

5 LPSI Pump 1 FV = 0.0004 + 0.0003 + 0 + 0.0005 + 0.0029 = 0.0041

LPSI Pump 1 RAW 3가 ,

1: CCF LPSI Pump 1 RAW = 22.1099  
 2: CCF LPSI Pump 1 RAW = 1.2054  
 3: LPSI Pump 1 P RAW = 1 + FV\*(1-P)/P  
 , P = 1.92E-5 + 1.76E-3 + 2.4E-4 + 2.3E-3 + 1.36E-04 = 0.0044552  
 RAW = 1 + 0.0041 \* (1 - 0.0044552)/0.0044552 = 1.91617

DynaRM<sup>12</sup> , LPSI Pump 1 RAW 1.326 .  
 , 1 가 , NEI 가 1.2054 ( , NEI  
 CCF RAW 가 RAW<sub>ccf</sub> = 22.1099 > 20 , LPSI Pump 1  
 ), South Texas GQA 가 22.1099 가 (RAW>2 가  
 LPSI Pump 1 ).  
 , RAW 1.91617 (RAW<2 가 LPSI Pump 1  
 ) 가 .

(3) , P NEI 6 .

6 A P A 가  
 , 0.0084 ( = 0.00285 + 0.0002 + 0.00498 + 0.000075 + 0.00015 + 0.00015)가 . ,  
 A FV 0.0108 , (3) A RAW .

$$RAW = 1 + 0.0108 \cdot (1 - 0.0084) / 0.0084 = 2.27$$

6 NEI CCF RAW 가 RAW 가 , A RAW  
 1.7 , 2.27  
 RAW RAW 가  
 RAW= 2.27 > 2 가 A가 , NEI CCF  
 RAW CCF RAW = 54 > 20

6.

Component Failure Mode	P	FV	RAW	CCF RAW
1) Valve 'A' Fails to Open	0.00285	0.002	1.7	n/a
2) Valve 'A' Fails to Remain Closed	0.0002	0.00002	1.1	n/a
3) Valve 'A' In Maintenance	0.00498	0.0035	1.7	n/a
4) Common Cause Failure of Valves 'A' & 'B' & 'C' to Open	0.000075	0.004	n/a	54
5) Common Cause Failure of Valves 'A' & 'B' to Open	0.00015	0.0007	n/a	5.6
6) Common Cause Failure of Valves 'A' & 'C' to Open	0.00015	0.0006	n/a	4.9
<b>NEI</b>		0.0108 (sum)	1.7 (max)	54 (max)
	0.0084	0.0108	2.27	

NEI 2  
 RAW , CCF RAW RAW CCF RAW RAW  
 , CCF RAW 가 , CCF RAW 가  
 가 3.48 , 1 CCF RAW가 3220 , RAW  
 , 1 100 가 가  
 가 2 3  
 , CCF 가 RAW CCF RAW 가  
 , South Texas NEI GQA , CCF RAW  
 RAW 가 RAW



1. [Redacted], [Redacted], " [Redacted] " KAERI/TR-2432/2003, 2003 3
2. NRC, "An Approach for Plant-Specific, Risk-Informed Decision-making: Graded Quality Assurance", Regulatory Guide 1.176, 1998. 8
3. NRC, Options for Risk-Informed Revisions to 10 CFR Part 50 - "Domestic Licensing of Production and Utilization Facilities", SECY-98-300, 12/23/1998
4. NRC, Official Transcript of Proceedings of ACRS Reliability and Probabilistic Risk Assessment Subcommittee, Feb. 22, 2002
5. NEI 00-04 , "Industry Guideline for Risk-Informed Categorization and Treatment of Structures, Systems, and Components, Draft, March, 2000
6. NEI 00-04 (Draft-Revision D), "10 CFR 50.69 SSC Categorization Guideline," May 2003.
7. Y. Dutuit, A. Rauzy, " Efficient algorithms to assess component and gate importance in fault tree analysis " , Reliability Eng. And System Safety, Vol 72, 2001
8. S. Martorell,et.al., " Safety-related equipment prioritization for reliability centered maintenance purposes based on a plant specific level 1 PSA", Reliability Eng. And System Safety, Vol 52, 1996
9. I.B. Wall, D.H. Worledge, "Some Perspectives on Risk Importance Measure", PSA '96, Utah, U.S.A, 1996
10. NEI, White Paper for RAW, Dec. 1, 2002, "Importance Measures and Their Use in SSC Screening During Risk Significance Categorization"
11. "Ulchin Units 3&4 Final Probabilistic Safety Assessment", [Redacted] , 1995
12. [Redacted], " [Redacted] 3,4 [Redacted] ", [Redacted] , '2002 [Redacted] , 2002, 10