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Fragility Assessment of Piping System in Ulchin 56 NPP based on JNES Results

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1. Introduction

A Piping system is one of the most important systems in NPP, because a piping system carries coolant of NPP system. Failure of piping system reveals LOCA (loss of coolant accident) which can cause core damage. LOCA divide as large, medium and small LOCA according to a size of piping system. Even though LOCA is one of the most important accidents in NPP, LOCA is only considered in the case of internal event in Korea. But JNES (Japan Nuclear Energy Safety Organization) already performed a fragility analysis about piping systems in PWR and BWR system in Japan. And also Japan considered a failure of piping system in the case of seismic event. In this study, fragility results of Japanese NPP were investigated and fragility of piping system in Korea was evaluated by applying to Japanese method.

2. Seismic Fragility Assessment of Piping System in Japanese NPP

JNES already performed seismic fragility analysis for all kinds of NPP in Japan. In the case of 2 loop PWR system, 13 piping systems were selected for seismic fragility evaluation. Table 1 shows target piping system list of Japanese 2-loop PWR system. JNES already evaluated about limit capacity of each piping system. As shown in Table 1, limit accelerations of piping system are different between piping and support. Limit acceleration of piping system is much higher than that of support of piping system. As a result, it can be notice that failure of piping system is governed by seismic capacity of support.[JNES, 2006]

Table 1. Piping systems for fragility evaluation

	Piping System	Diameter (in)	Natural Frequency	Limit Acc.	
				Piping	Support
1	Pressurizer Surge	10	12	56	13
2	Pressurizer Spray	3	11	71	17
3	Pressurizer Release	3	15	28	9
4	Pressurizer Safety Valve	4	50	41	36
5	Residual heat removal(CV)	8	13	32	13
6	Residual heat removal (outside of CV)	6	20	38	7.9
7	Safety injection(CV)	8	13	41	13
8	Spray Link	10	14	77	29
9	Vertical (CV)	6	12	125	40
10	Main steam(CV)	30	16	33	6.8
11	Main steam(outside of CV)	28	12	39	14
12	Main feed water(CV)	16	16	42	6.8
13	Main feed water(outside of CV)	16	11	58	19

JNES developed a failure probability of failure for piping system of 2-loop PWR in Japan as shown in Table 2. As shown Table 2, failure probability of piping system was determined as each peak acceleration level. So we can determine a failure probability of piping system at each acceleration level. But if the results shown in Table 2 apply to Korean NPP, the results should be transformed as median probability of failure and uncertainty value. The failure probabilities are transformed as median value and uncertainty value as shown in Table 3. In Table 3, median failure probabilities are shown in 'gal' and 'g'.

Table 2. Failure probability of piping system in 2-loop PWR in Japan

	failure probability (unit:gal)						
	300	450	600	750	900	1100	1300
1	8.E-13	9.E-10	8.E-08	1.E-06	1.E-05	9.E-05	5.E-04
2	4.E-05	1.E-03	7.E-03	2.E-02	4.E-02	9.E-02	2.E-01
3	2.E-07	3.E-05	1.E-03	6.E-03	2.E-02	6.E-02	2.E-01
4	3.E-34	1.E-30	1.E-25	7.E-22	9.E-20	1.E-17	8.E-16
5	2.E-07	2.E-05	4.E-04	2.E-03	6.E-03	2.E-02	5.E-02
6	2.E-07	2.E-05	9.E-04	1.E-02	4.E-02	1.E-01	2.E-01
7	1.E-06	7.E-05	1.E-03	5.E-03	1.E-02	4.E-02	7.E-02
8	9.E-19	2.E-14	4.E-12	3.E-10	3.E-09	8.E-08	1.E-06
9	2.E-35	9.E-29	6.E-25	2.E-21	4.E-19	8.E-17	7.E-15
10	6.E-04	2.E-02	1.E-01	2.E-01	4.E-01	6.E-01	8.E-01
11	4.E-08	3.E-05	1.E-03	1.E-02	3.E-02	6.E-02	9.E-02
12	6.E-04	2.E-02	1.E-01	2.E-01	4.E-01	6.E-01	8.E-01
13	2.E-12	3.E-08	3.E-05	9.E-04	3.E-03	9.E-03	2.E-02

Table 3. Failure probability of piping system in Japan

	median(gal)	beta	median(g)
1	4.36E+03	0.368	4.45E+00
2	1.82E+03	0.390	1.85E+00
3	1.61E+03	0.250	1.64E+00
4	2.13E+04	0.351	2.18E+01
5	2.58E+03	0.417	2.64E+00
6	1.81E+03	0.389	1.84E+00
7	2.71E+03	0.501	2.77E+00
8	6.64E+03	0.343	6.77E+00
9	1.46E+04	0.314	1.49E+01
10	9.90E+02	0.352	1.01E+00
11	2.99E+03	0.627	3.05E+00
12	9.90E+02	0.352	1.01E+00
13	3.86E+03	0.530	3.93E+00

3. Seismic Fragility Evaluation for Piping System in Ulchin 56 NPP

For the evaluation of fragility of piping system at Ulchin 56 NPP, it assumed that piping system of Japan and Korea are same. For the assessment of response of piping system in Ulchin 56 NPP, FRS of containment and PAB were used. One of FRS is shown in Figure 1. A seismic fragility was determined by using equation (1) and (2)

$$A_C = \frac{F_C}{F_S} \times A_S \qquad (1)$$

$$\mathrm{HCLPF} = A_C \cdot e^{-1.65(\beta_r + \beta_u)} \qquad (2)$$

where, A_C is a critical acceleration, A_S is an acceleration response of natural frequency of piping system, F_C is critical stress, $F_S$is a response caused by seismic load, HCLPF is a high confidential and low probability of failure and β_r and β_u are a uncertainty value.

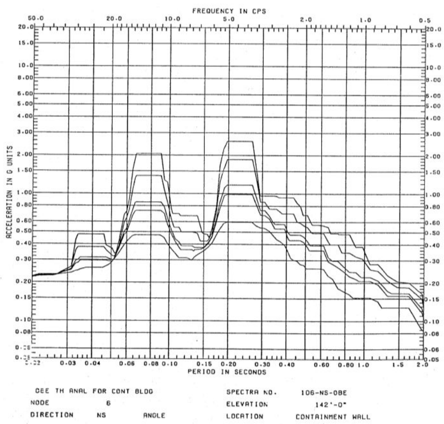

Figure 1. Example of Ulchin 56 NPP FRS (142' containment) [KEPCO, 1997]

Median failure probability and HCLPF are summarized as Table 4 to Table 7 according to the location of containment and PAB. As shown in Table 4 to 7, fragility values of some piping system in Ulchin NPP are lower than that of JNES results. As shown in Table 4 to 7, the failure probability of piping system in Ulchin 56 NPP is not enough for compare of Japanese NPP. Although Japanese seismic design level is much higher than that of Korea NPP, fragility of some piping system might be not sufficient so detail analysis should be needed and failure of piping system should be considered in seismic PSA in Korea.

Table 4. Median probability of failure of piping system in Ulchin 56 NPP (in the containment vessel)

	Median	Median according to FRS of CV									
Piping system	JNES	100NS	100EW	111NS	111EW	122NS	122EW	132NS	132EW	142NS	142EW
Pressurizer Surge	4.45	3.20	2.67	2.53	2.00	2.00	1.66	1.85	1.50	1.71	1.41
Pressurizer Spray	1.85	2.75	2.44	2.32	1.83	1.83	1.52	1.69	1.38	1.57	1.29
Pressurizer Release	1.64	4.00	3.33	3.16	2.50	2.50	2.07	2.31	1.88	2.14	1.76
Pressurizer Safety Valve	21.76	40.00	38.46	35.71	33.33	31.25	28.57	28.57	26.32	26.32	23.81
Residual heat removal(CV)	2.64	3.47	2.89	2.74	2.17	2.17	1.79	2.00	1.63	1.86	1.53
Residual heat removal (outside of CV)	1.84										
Safety injection(CV)	2.77	3.47	2.89	2.74	2.17	2.17	1.79	2.00	1.63	1.86	1.53
Spray Link	6.77	3.73	3.11	2.95	2.33	2.33	1.93	2.15	1.75	2.00	1.65
Vertical (CV)	14.87	3.20	2.67	2.53	2.00	2.00	1.66	1.85	1.50	1.71	1.41
Main steam(CV)	1.01	7.11	5.82	5.82	4.27	4.57	3.76	3.56	3.20	3.20	2.67
Main steam(outside of CV)	3.05										
Main feed water(CV)	1.01	7.11	5.82	5.82	4.27	4.57	3.76	3.56	3.20	3.20	2.67
Main feed water(outside of CV)	3.93										

Table 5. HCLPF of piping system in Ulchin 56 NPP (in the containment vessel)

	HCLPF	HCLPF according to FRS of CV									
Piping system	JNES	100NS	100EW	111NS	111EW	122NS	122EW	132NS	132EW	142NS	142EW
Pressurizer Surge	1.886	1.36	1.13	1.07	0.85	0.85	0.70	0.78	0.64	0.73	0.60
Pressurizer Spray	0.621	0.92	0.82	0.78	0.61	0.61	0.51	0.57	0.46	0.53	0.43
Pressurizer Release	0.695	1.70	1.41	1.34	1.06	1.06	0.88	0.98	0.79	0.91	0.75
Pressurizer Safety Valve	10.782	19.82	19.06	17.70	16.52	15.49	14.16	14.16	13.04	13.04	11.80
Residual heat removal(CV)	1.035	1.36	1.13	1.07	0.85	0.85	0.70	0.79	0.64	0.73	0.60
Residual heat removal (outside of CV)	0.690										
Safety injection(CV)	1.036	1.30	1.08	1.03	0.81	0.81	0.67	0.75	0.61	0.70	0.57
Spray Link	2.958	1.63	1.36	1.29	1.02	1.02	0.84	0.94	0.76	0.87	0.72
Vertical (CV)	7.368	1.59	1.32	1.25	0.99	0.99	0.82	0.91	0.74	0.85	0.70
Main steam(CV)	0.441	3.11	2.54	2.54	1.86	2.00	1.64	1.55	1.40	1.40	1.17
Main steam(outside of CV)	1.123										
Main feed water(CV)	0.441	3.11	2.54	2.54	1.86	2.00	1.64	1.55	1.40	1.40	1.17
Main feed water(outside of CV)	1.428										

Table 6. Median probability of failure of piping system in Ulchin 56 NPP (in the PAB)

	Median								
	JNES	U56 (PAB)							
Piping system		100EW	100NS	125EW	125NS	144 EW	144 NS	165 EW	165 NS
Residual heat removal (outside of CV)	1.842	2.110	1.892	1.704	1.820	1.816	1.775	1.362	1.432
Main steam(outside of CV)	3.046	2.667	3.457	1.735	2.074	1.346	1.481	1.111	1.148
Main feed water(outside of CV)	3.934	3.423	3.762	2.354	2.123	1.827	1.526	1.434	1.176

Table 7. HCLPF of piping system in Ulchin 56 NPP (in the PAB)

	HCLPF								
	JNES	U56 (PAB)							
Piping system		100EW	100NS	125EW	125NS	144 EW	144 NS	165 EW	165 NS
Residual heat removal (outside of CV)	0.690	0.791	0.709	0.639	0.682	0.680	0.665	0.510	0.537
Main steam(outside of CV)	1.123	0.984	1.275	0.640	0.765	0.496	0.546	0.410	0.423
Main feed water(outside of CV)	1.428	1.243	1.366	0.855	0.771	0.663	0.554	0.521	0.427

5. Conclusions

In this study, fragility assessment results for piping system in Japan NPP were determined and apply to Korean NPP. Seismic capacity of some piping system in Korea is lower than that of Japan NPP. Because a seismic design level of Korea is much lower than that of Japan, safety of NPP might not be a big problem. But seismic fragility evaluation for piping system should be needed and failure of piping system should be considered in seismic PSA in Korea.

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