

Best Estimate Analysis of OPR 1000 ATWS Risk for Probabilistic Safety Assessment

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1. Introduction

The Anticipated Transient Without Scram (ATWS) is the event which rods can not drop to the core when the reactor trip is required. For the best-estimate analysis of OPR 1000 ATWS risk, we needed to review processes such as the standard method for a transient event analysis, the development of the thermal-hydraulic code input for Unfavorable Exposure Time (UET) calculation, and the evaluation of initiating events.

In this study, the initiating events frequency and UET value of OPR 1000 were re-evaluated with the best estimate methodology. Based on these results, the probabilistic safety assessment also was performed.

2. UET Calculation and Initiating Events Frequency Re-assessment

2.1 The UET Calculation of OPR 1000

The Moderator Temperature Coefficient (MTC) is the variable depending on the cycle burn-up. To assess the impact of this variable, we use the fractional period, UET, in which the reactor pressure exceeds the acceptance criteria of ASME condition III. The RCS pressure limit of ASME criteria is 3,200 psig.

In addition, the main feedwater availability is also one of important parameters that impact on UET calculation because it is related with secondary inventory and heat removal capability. The events of Loss of Main Feedwater (LOFW), Loss of Condensate Vacuum (LOCV) and Loss of Offsite Power (LOOP) are unavailable using main feed water. However, the events of Loss of Component Cooling Water (LOCCW) and General Transients (GTRN) are available using main feed water. Therefore, LOCCW and GTRN were excluded from loss of feedwater events analysis.

The representative cases of UET calculation are LOFW and GTRN. The results of UET calculation for OPR 100 are shown in Table 1.

Unlike other units, Ulchin unit 5,6 initial core UET value is zero which is caused by core characteristics. In case of OPR 1000 equilibrium core, the UET is calculated zero because equilibrium core has enough negative reactivity.

Table 1. Results of UET calculation for OPR 1000

	Title	Ulchin Unit 3,4	Ulchin unit 5,6	Yeong gwang unit 3,4	Yeong gwang unit 5,6
		UET (%)	UET(%)	UET (%)	UET (%)
Initial core	LOFW	4.5	0	6.2	4.0
	GTRN	0	0	0	0
Equilibrium core	LOFW	0	0	0	0
	GTRN	0	0	0	0

2.2 Re-assessment of Initiating Event Frequency for OPR 1000

To revise the initiating event frequencies, the reactor trip events of domestic nuclear plants for ten years (1997 ~ 2006) were surveyed in accordance with the EPRI criteria. The results are used to calculate the frequencies of transient events and a resultant ATWS frequency.

Table 2 shows results of the initiating event frequencies of OPR 1000.

The Large Brake Loss of Coolant Accident (LLOCA), Medium Brake Loss of Coolant Accident (MLOCA), Interface Surface Loss of Coolant Accident (ISLOCA) and Reactor Vessel Rupture (RVR) are excluded from initiating events because they are transferred to ATWS. Based on results of Table 2, the summation of initiation events frequencies which cause ATWS was evaluated as 1.0/ry.

Table 2. Results of initiating event frequencies of OPR 1000

Initiating event	Ulchin Unit 3,4 (RY)	Yeong gwang unit 3,4 (RY)	Ulchin unit 5,6 (RY)	Yeong gwang unit 5,6 (RY)
LSSB	1.03E-02	1.03E-02	1.03E-02	1.03E-02
LOFW	6.44E-02	6.44E-02	6.44E-02	6.44E-02
LOCV	4.45E-02	4.45E-02	4.45E-02	4.45E-02
LOCCW	2.42E-01	1.77E-01	2.33E-01	2.20E-01
LOAC	1.36E-02	1.36E-02	1.36E-02	1.36E-02
LODC	5.93E-04	5.93E-04	5.93E-04	5.93E-04
LOOP	3.68E-02	3.68E-02	3.68E-02	3.68E-02
GTRN	5.92E-01	5.92E-01	5.92E-01	5.92E-01
SGTR	6.53E-03	6.53E-03	6.53E-03	6.53E-03
SLOCA	4.73E-04	4.73E-04	4.73E-04	4.73E-04
Total	1.01	0.95	1.00	0.99

3. ATWS Risk Assessment of OPR 1000

3.1 ATWS Risk Assessment Results

The ATWS risk assessment of OPR 1000 was conducted with the results of re-assessment of initiating events and UET calculation. Also, in order to calculate ATWS risk in initial and equilibrium core, ATWS event tree of existing PSA model was modified. The quantification results of initial core are shown in Table 3.

Table 3. Quantification results of initial core for OPR 1000

Unit	Before UET re-evaluation		After initiating event frequency and UET re-evaluation	
	ATWS CDF(/yr)	Total CDF(/yr)	ATWS CDF(/yr)	Total CDF(/yr)
Ulchin unit 3&4	1.30E-07	5.44E-06	2.45E-07	5.50E-06
Yeonggwang unit 3&4	1.25E-07	4.74E-06	3.11E-07	4.50E-06
Ulchin unit 5&6	1.30E-07	5.65E-06	1.37E-08	5.64E-06
Yeonggwang unit 5&6	1.29E-07	5.46E-06	2.15E-07	5.70E-06

The quantification was conducted for OPR 1000 PSA models which were modified with re-evaluated initiating events and UET results. The ATWS CDF of Ulchin unit 3&4, Yeonggwang units 3,4,5,6 are increased because UET is larger than existing UET of PSA model.

In case of equilibrium core, the calculated ATWS CDF and total CDF using modified UET and re-evaluated initiating events are less than the existing values. The results of equilibrium core are shown in Table 4.

Table 4. Quantification results of equilibrium core for OPR 1000

Unit	Before UET re-evaluation		After initiating event frequency and UET re-evaluation	
	ATWS CDF(/yr)	Total CDF(/yr)	ATWS CDF(/yr)	Total CDF(/yr)
Ulchin unit 3&4	1.30E-07	5.44E-06	1.37E-08	5.26E-06
Yeonggwang unit 3&4	1.25E-07	4.74E-06	2.07E-08	4.20E-06
Ulchin unit 5&6	1.30E-07	5.65E-06	1.37E-08	5.64E-06
Yeonggwang unit 5&6	1.29E-07	5.46E-06	1.35E-08	5.50E-06

OPR 1000 ATWS risk was analyzed using re-evaluated initiating events and 1% UET and the results is tabulated as below. The results show that ATWS CDF is decreased due to UET. Total CDF of Ulchin unit 3&4 and Yeonggwang unit 3&4 were decreased, but Ulchin unit 5&6 and Yeonggwang 5&6 were increased.

Table 5. Results of using re-evaluated initiating events and 1% UET

Unit	Existing PSA model		Reflecting initiating events re-assessment and using UET value 0.01	
	ATWS CDF (/yr)	Total CDF(/yr)	ATWS CDF (/yr)	Total CDF(/yr)
Ulchin unit 3&4	1.30E-07	5.44E-06	6.51E-08	5.31E-06
Yeonggwang unit 3&4	1.25E-07	4.74E-06	6.06E-08	4.25E-06
Ulchin unit 5&6	1.30E-07	5.65E-06	6.47E-08	5.69E-06
Yeonggwang unit 5&6	1.29E-07	5.46E-06	6.40E-08	5.55E-06

4. Conclusion

In this paper, the initiating event frequency and UET value were re-evaluated to optimize OPR 1000 ATWS analysis. Also, the safety assessment analysis was performed through OPR 1000 PSA model re-quantification.

The reactor trip frequency of OPR 1000 which causes ATWS is evaluated as 1.0/ry. The UET value is evaluated in initial and equilibrium core condition, respectively.

Based on this study, it is reasonable to apply 7% of UET for constructing Optimized Power Reactors, and it is conservative that operating plant has 1% of UET. In case of new design characteristic plants, such as Shin-Kori unit 3&4, the UET must be calculated using another best estimate analysis methodology.

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