Best Estimate Analysis of OPR 1000 ATWS Risk

Ki-Yeoul Seong*, Jong-Ho Lee, Seok-Won Hwang, Jang-Hwan Na
Korea Hydro & Nuclear Power Co., Ltd.
25-1, Jang-dong, Yuseong, Daejeon 305-343, Korea
sskyein@khnp.co.kr

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. The cause for this event is an electrical and/or mechanical failure of the RPS (Reactor Protection System).

For the OPR 1000 ATWS best-estimate analysis, we needed the processes which included the review of the standard method for a transient event analysis, the development of the thermal-hydraulic code input for UET (Unfavorable Exposure Time) calculation, and the evaluation of initiating events.

In this study, the methodologies for the ATWS risk and UET evaluation were reviewed and the initiating events were re-evaluated. Based on these results, the safety assessment also was performed.

2. Methodology for ATWS Risk Assessment

2.1 SECY-83-293 Methodology

In the SECY-83-293 analysis, the effects of initiating events, turbine conditions, the electric reliability & mechanical reliability of RPS, UET values, auxiliary feed water operating conditions, and the boron injection effects of CVCS were considered for the ATWS risk analyses.

For this analysis, an ATWS event analysis model was specifically developed based on the OPR 1000 because the analysis results depended on nuclear power plant types. The ATWS event tree is shown in Figure 1.

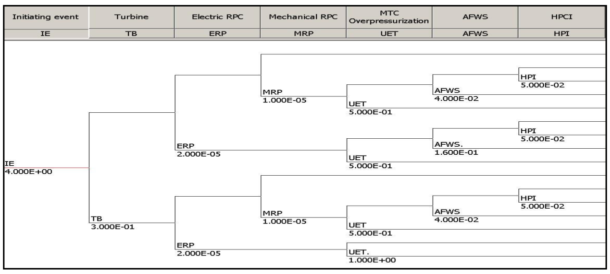

Figure 1. ATWS event tree in SECY-83-293

2.2. Re-assessment of Initiating Event Frequency

The KAERI/TR-2957[1] was referred to calculate the initiating frequencies for transient events. In case of the LOCA group, the data from ALWR PRA KAG [3] were used.

For the initiating event frequency revision, 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 frequency of transient events and a resultant ATWS frequency.

Based on these transient event frequencies, the ATWS frequency of OPR 1000 was calculated by multiplying the frequencies of the initiating events which were transferred to ATWS. The transient events for ATWS include loss of feed water, loss of an external load, loss of offsite power, loss of condenser vacuum, loss of component cooling water and a general transient, etc. It was supposed that the ATWS frequency had a log-normal distribution. Table 1 shows the OPR 1000 ATWS frequency. The ATWS frequency was reduced by half of the previous work because the transient events frequencies were reduced based on the recent operating experiences.

Table 1. Comparison of ATWS Frequency Results

Plant	ATWS freq. (/yr) (PSA model, 2004)	ATWS freq. in this work (/yr)
OPR 1000	1.03E-05	5.32E-06

2.3 The Analysis Method for UET Calculation

The primary system pressure and temperature are raised due to the loss of secondary heat removal capability. As the primary system pressure and temperature are increased, the PSV (Pressurizer Safety Valve) and/or MSSV (Main Steam-line Safety Valve) are fully opened to release the steam from the primary system. Finally, the reactor power is decreased by a negative moderator temperature coefficient (MTC) as the temperature is increased. The 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 turbine condition is also one of important parameters that impact on system behavior because it is related with secondary inventory and heat removal capability. Therefore, the representative turbine trip case and non-turbine trip case were analyzed. The effects of other reactivity parameters such as FTC (Fuel Temperature Coefficient), Doppler reactivity, and boron concentration were not considered in this analysis.

3. ATWS Risk Assessment of OPR 1000

3.1 ATWS Risk Assessment Results

The initiating event frequency and system failure probabilities of the SECY-83-293 ATWS event tree were changed to apply to OPR 1000. For example, the failure probability of turbine trip, reactor protection, auxiliary feed water, and high pressure safety injection system were changed to reflect the current plant system performance. The evaluation cases of ATWS event safety assessment in OPR 1000 are shown in Table 2.

Table 2. ATWS Risk Evaluation Cases of OPR 1000

Cases	Description	Remark
Base Case	Most conservative case	SECY-83-293
Option 1	DPS considered	SECY-83-293
Option 2	DPS & additional safety valve installation considered	SECY-83-293
Case 1	UET changed	from Base Case
Case 2	UET & Initiating event freq. changed	-
Case 3	UET, initiating event freq., and DPS failure prob. changed	-
Case 4	- UET, initiating event freq., and DPS failure prob. changed - AFW/HPSI failure prob. changed	-
U34-1	Before Ulchin unit 3&4 best-estimate analysis conditions	-
U34-2	Ulchin unit 3&4 best-estimate analysis conditions	-

The result of risk assessment model quantification showed that the U34-2 case using the best-estimate analysis condition of Ulchin unit 3&4 has the lowest CDF (4.93E-08/yr). The U34-2 case considered the UET as 0.01, the ATWS frequency as 5.32E-06/yr, and the failure probability of the auxiliary feed water system as 1.21E-06.

3.2 Sensitivity Analysis

All of the OPR 1000 have installed the ATWS mitigating system which is called as the diverse protection system (DPS). The DPS and auxiliary feed water system were analyzed for sensitivity study. In order to understand the effects of these systems on the risk quantification results, the sensitivity analyses were performed under the following system configurations.

The considered cases are listed in Table 3.

Table 3. Calculation Condition and Sensitivity Results

Cases	Description	CDF	UET
Case 1	Base Case	1.08E-7	1.6%
Case 2	DPS failure prob. considered	4.95E-8	1.6%
Case 3	Aux. feed water flow (100%/50%) considered	9.70E-8	1.6%/7%
Case 4	DPS & Aux feed water flow (100%/50%) considered	4.94E-8	1.6%/7%

The DPS actuation failure probability used in this study was about 2.00E-02. The auxiliary feed water system failure probability was used in two cases. One failure probability was 2.20E-03 and this value was calculated on the supposition that all auxiliary feed water pumps are failed. The failure probability was changed to 5.50E-03 when auxiliary feed water system had only 50 % flow capacity. Similarly, each of the human error probability was respectively considered as 2.84E-03 and 7.11E-04.

When the DPS failure probability was applied, the new CDF was reduced by half of the CDF without DPS. The CDF of case 2 was about ten percent less than that of case 1 due to the auxiliary feed water flow capacity effect. Relatively, the effect of auxiliary feed water flow capacity was less significant than the DPS failure effect.

4. Conclusion

In this paper, ATWS risk assessment methodologies and initiating events were reviewed to optimize OPR 1000 ATWS analyses. Also, the safety assessment and sensitivity analysis were performed.

When the DPS, MTC effect and revised initiating event frequency were considered, the resultant CDF was less than the base case which was the most conservative case in SECY-83-293.

Consequently, it is expected that the ATWS risk could be lowered through the initiating event reassessment reflecting the recent plant performance. Furthermore, if we use the optimized UET value which is obtained from a thermal hydraulic analysis, ATWS risk could be much lower than currently evaluated risk.

REFERENCES

[1] "An Estimation of Risk Impact of Anticipated Transients without Scram for a KSNP," KAERI, 2006.
[2] "Rates of initiating events at U.S. nuclear power plant: 1987-1995," NUREG/CR-5750, USNRC, 1999.
[3] "ALWR URD: Volume II: Chapter 1, Appendix A PRA key assumptions and groundrules," EPRI, 1992.
[4] "ATWS Rulemaking Issue, 1983," U.S. NRC SECY-83-293.