Preliminary Analyses on the ATWS events for OPR1000 using RETRAN-3D code

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1. Introduction

An Anticipated Transient Without Scram (ATWS) event is the failure of rod drop to the core when the reactor trip is required. The reason for this event is electrical and/or mechanical failure of the Reactor Protection System (RPS). The possibility of this event is steadily raised since 1960s and final ATWS Rule[1)] became effective on 1984 from USNRC. This rule was issued to require design changes to reduce the expected ATWS frequencies and consequences. The technical basis for the ATWS rule is provided in SECY-83-293.

All of the domestic nuclear power plants had installed the ATWS mitigating facility to incorporate into this requirement; ATWS mitigation System Actuation Circuitry (AMSAC) for WH plant and Diverse Protection System (DPS) for OPR1000. Recently, the effectiveness of the ATWS mitigating capability is raised for individual plant. So, in this paper, UCN 3,4 specific analyses on ATWS event are performed using RETRAN-3D code.

2. Analysis method

● Initial and Boundary condition

An ATWS event is a kind of Common Mode Failure (CMF) event, the failure of reactor scram system simultaneously with the initiating event. In this concern, the initiating event is restricted to the ANS condition II event. Also, the best estimate analyses are permitted. So, the RETRAN-3D code is used in this analysis with 100% nominal power condition as shown in Table 1.

Table 1. Initial and Boundary Condition

Variable	Plant	RETRAN	Remark
Rx Power (MWth)	2815.0	2815.7	Nominal
PZR P(psia)	2250.0	2250.0	
RCS Temp (˚F)			
Thot	621.1	620.8	
Tcold	564.4	566.0	
RCS flowrate /RCP	8437.5	8435.0	
SG P(psia)	1070.0	1075.3	

● Analysis Case

ATWS is the event that the reactor trip is required but the reactor trip is not occurred. In this situation, the primary system pressure and temperature is increased due to the short of secondary heat removal capability. As the primary system pressure and temperature build up, the PSV and/or MSSV are fully opened and relief the steam generated in the core. Finally, the reactor power is decreased by negative moderator temperature coefficient (MTC) as temperature rises. The MTC is the variable that is dependent on the cycle burn-up. To assess the impact of this variable, the Unfavorable Exposure Time (UET), the fractional period that the reactor pressure exceed the acceptance criteria of ASME condition III (normally, RCS pressure limit is set to 3200 psig) is used.

In addition, the turbine condition is also an important parameter that impacts on the system behavior because it is related to the secondary inventory and heat removal capability. So, representative turbine trip case and non-turbine trip case is analyzed. The effects of other reactivity parameter, such as FTC, Doppler reactivity, boron concentration are not considered in these analyses. Minimum PSV and MSSV flow capacity is used. Auxiliary feedwater system deliver the cooling water to SG at 60sec after DPS signal is generated.

3. Analysis Result

● Case 1 : Loss of Condenser Vacuum

Loss of condenser vacuum (LOCV) is chosen as a representative turbine trip case.

Table 2. ATWS Event Scenario with LOCV

Time	Event
0.0s	Loss of condenser vacuum occurs without reactor scram
1.8s	PZR hi pressure reached
6.1s	PSVs open
57.1s	SG DPS signal generates
110.5s	PZR solid
116.2s	Aux. feedwater pump actuates
136.8s	Peak PZR pressure reached (3053.8psia)
340.9s	PSVs close

After LOCV occurs at 0.0s, PSV open at 6.1s. Steam Bypass Control System(SBCS) discharge the main steam to the atmosphere and SG level rapidly decreased and

dryout at 115s. DPS signal is generated at 57.1s and the AFW deliver the water to the SG at 116.2s. So, secondary heat removal is maintained and the value of MTC which RCS pressure does not exceed 3200psig is -9pcm/°F and peak pressure reaches to 3053.8psia as shown in table 2. Based on the representative MTC curve of ulgin 3 cycle 5, LOCV event does not challenge the RCS integrity.

- **Case 2 : Loss of All Feedwater event**

Normally, Loss of All Feedwater (LOAF) event is the most limiting case of ATWS event and is chosen as a representative turbine trip case[2]. After the downcomer/economizer feedwater is not provided at 0.0s, but the turbine is continuously working and SG dryout occurs at 93.0s. Then, PSV and MSSV remove the heat generated in the core and finally peak pressure reaches to 3061.9 psia at 111.5s as shown in Fig 1,2,3. Then reactor power decreased below 10% power level and AFW removed the heat indirectly. The MTC which satisfies ASME service level C limit (3200psig) is -11pcm/°F in this case. The detailed event scenario is shown in table 3.

Based on the representative MTC curve of ulgin 3 cycle 5, LOAF event UET is nearly 7%.

Table 3. ATWS Event Scenario with LOAF

Time	Event
0.0s	Loss of main feedwater occurs without reactor scram
6.7s	PZR hi pressure reached
44.1s	SG DPS signal generates
66.2s	PSVs open
96.4s	PZR solid
104.1s	Aux. feedwater pump actuates
111.5s	Peak PZR pressure reached (3061.9psia)
292.3	PSVs close

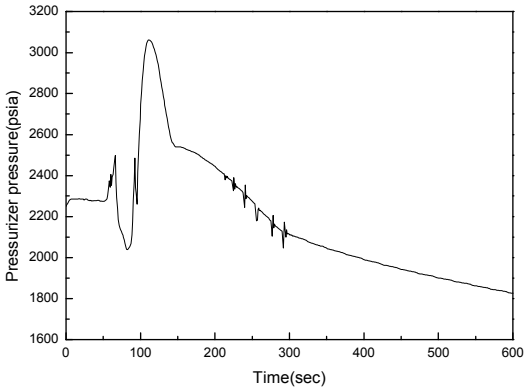

Figure 1. Pressurizer pressure for LOAF

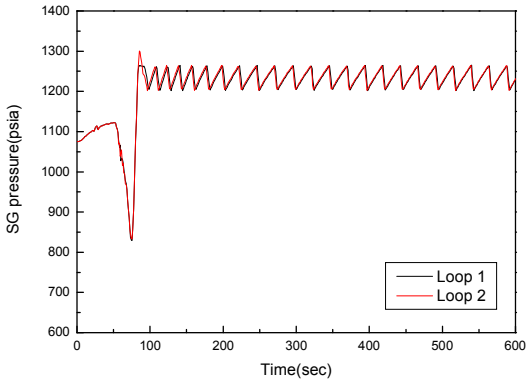

Figure 2. Steam generator pressure for LOAF

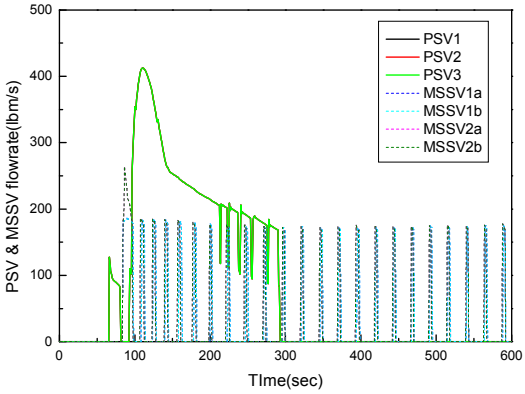

Figure 3. PSV & MSSV flowrate for LOAF

4. Conclusion

A representative OPR1000 specific ATWS event analyses using RETRAN-3D code are performed. When ATWS is occurred after turbine trip event, results show that the RCS pressure is below the general acceptance criteria and RCS integrity is maintained. However, the ATWS event without turbine trip case shows that the RCS integrity is maintained after the 7% of core cycle. Several sensitivity analyses, for example, reactor power, boron concentration, PSV/MSSV availability, are required to assess overall impact of ATWS to CDF.

REFERENCES

[1] 10CFR50.62, Requirements for reduction of risk from ATWS events for LWR, USA

[2] S. I. Lee, et al., Comparative Analysis of ATWS for OPR1000 by using RETRAN-3D and CESEC-III codes, Proceedings of 2005 KNS Fall Meeting, Busan, Korea