Anticipated Transient Without SCRAM(ATWS) analysis using the RETRAN code

Bum soo Youn [a*], Jong beom Lee [a], Dong soo Song [a], Sang jun Ha[a]
[a]*KHNP CRI, Safety analysis group, 70 1312-gil Yuseong-daero Yuseong-gu, Daejeon, 304-343, KOREA*
[*]*Corresponding author: bsyoun0@khnp.co.kr*

1. Introduction

The purpose of this study is to evaluate the Anticipated Transient Without Scram(ATWS) Loss of Load(LOL) and Loss of Normal Feedwater(LOFW) events for the OPR1000 reactor. The analysis calculates the peak RCS and secondary system pressure for the LOL and LOFW ATWS events. The main product of this study is the ATWS evaluation of the OPR1000 reactor LOL and LOFW events. The results include a sequence of events and plots of key output parameters.

2. Methods and Results

The ATWS LOL and LOFW events were performed using the RETRAN-3D code. The use of the RETRAN-3D code provides advantages over the current CESEC-Ⅲ code. The LOL and LOFW Chapter 15 Non-LOCA transient analyses events are used as the starting point. ATWS analyses allow the use of nominal conditions and system setpoints. Hence, no uncertainties are applied to the initial conditions and equipment and system setpoints. This includes equipment and system response times; for example, main feedwater will not be instantly terminated in less than a second.

2.1 System Initial Conditions

This study used the OPR1000 steady state values. The values see the table I.

Table I: OPR1000 ATWS Steady state values

Parameter	**Value**
Core power	2815MWt
RCS flow rate	33750lbm/s
Cold leg temperature	564.89℉
Hot leg temperature	620.78℉
Pressurizer pressure	2250psia
Pressurizer water level	52.6%
Steam pressure	1102.75psia
Feed water flow rate	1771.91lbm/s
Steam flow rate	1771.91lbm/s
Steam generator water level	79.07%

2.2 Main Steam Safety Valves

OPR1000 reactor have 2 steam line to each SG, and 4 main steam safety valve to each steam line. MSSV minimum flow rate is $12.7x10^5$lbm/hr at 1397 psia. Table II show the opening set point of the MSSVs.

Table II: MSSV Setpoints

Nominal Setpoint Psig	**Opening Setpoint psia**	**3% Accumulation psia**	**5% Blowdown psia**
1250	1264.7	1302.2	1202.2
1290	1304.7	1343.4	1240.2
1315	1329.7	1369.15	1263.95

2.3 Plant Protected System

Plant protected system have 2 systems that are reactor protection system(RPS) and engineered safety feature actuation system(ESFAS).

The RPS is assumed to have a common mode failure that results in no signal being generated by the RPS. Instead the Diverse SCRAM System is used. It trips on High Pressurizer Pressure DSS at 2410 psia and has a response time of 1.15 seconds.

Table III summarize the ESFAS and response times. Since nominal conditions are being employed, no uncertainties are included in the ATWS ESFAS setpoints.

Table III: Engineered Safety Feature Actuation System

ESFAS	**Units**	**Setpoint**	**Response Time, sec**
DAFAS	% WR	22.2	1.25
MSIS	psia	885.5	1.15
SIAS	psia	1756	1.15

2.4 Loss of Load results

The peak RCS and secondary pressure for the ATWS LOL are 2580 and 1290psia, respectively. The Diverse Scram System (DSS) occurs at 1.15 seconds. The Diverse Auxiliary Feedwater Actuation System (DAFAS) occurs at 30.0 seconds. The pressurizer did not go solid. See Table IV for a sequence of events, and Fig. 1~Fig. 13 for the plots of key output parameters.

Table IV: Sequence of Events for Loss of Load ATWS

Time, seconds	**Event**	**Setpoint or Value**
0.0	Begin Steady State Run	
10.0	Turbine Trip	

10.0	Main Feed Ramp down	
11.0	Turb. Steam Flow Isolated	
17.7	High PZR. Pressure Alarm	2410 psia
18.8	DSS High Pressure Trip	
19.6	PSVs Open	2500 psia
20.0	Max. RCS Pressure Occurs	2579.9 psia
20.0	Main Feedwater Isolated	
20.6	CEAS Begin to Insert	
22.2	MSSVs Open (Bank 1)	1250 psia
22.8	MSSVs Open (Bank 2)	1290 psia
23.0	Max. SG Dome Pressure	1290 psia
26.0	Maximum Pressurizer Level	66%
26.8	PSVs Close	2040 psia
35.0	MSSVs Close (Bank 2)	1225.5 psia
45.1	MSSVs Close (Bank 1)	1187.5 psia
690.6	DAFAS Actuates	WR 22.2 %
720.7	AFW Actuated	
722.0	AFW Reaches SG	
1000.0+	RCS Temperature Stabilize	
1000.0+	Pressurizer Level Stabilize	

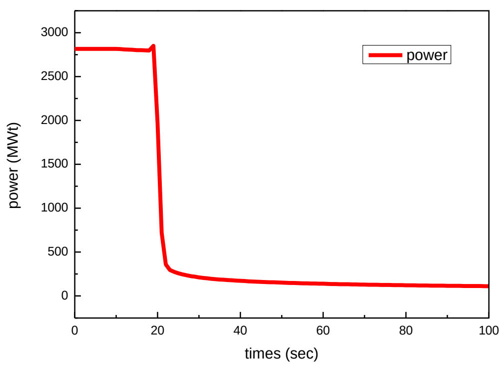

Fig. 1. Nuclear Power vs, Time for Loss of Load ATWS.

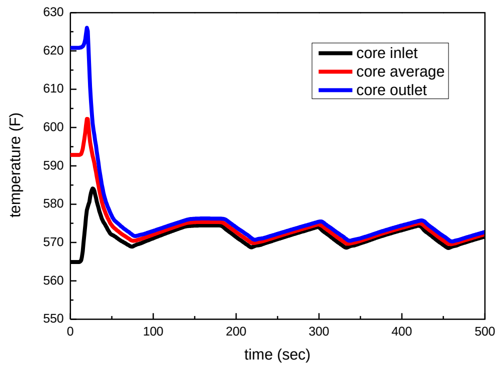

Fig. 2. RCS Temperature vs, Time for Loss of Load ATWS.

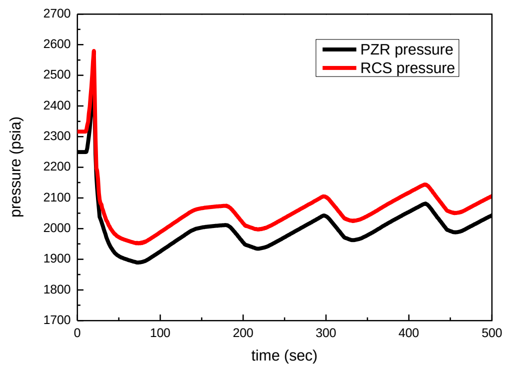

Fig. 3. Primary pressure for Loss of Load ATWS.

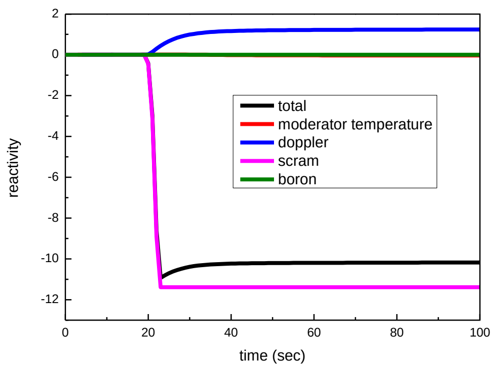

Fig. 4. Reactivity for Loss of Load ATWS

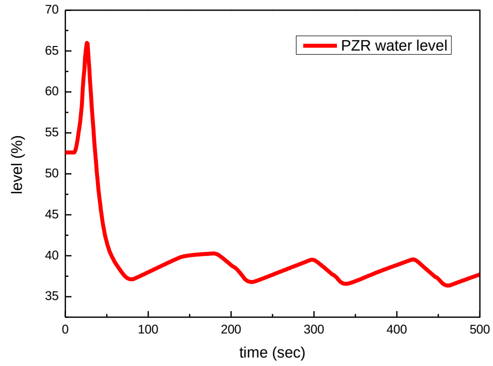

Fig. 5. Pressurizer Liquid Level for Loss of Load ATWS

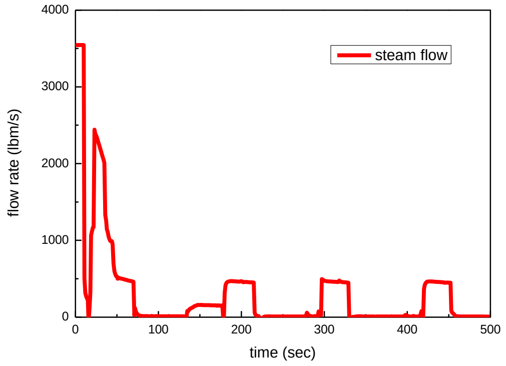

Fig. 8. Secondary Steam Flow for Loss of Load ATWS

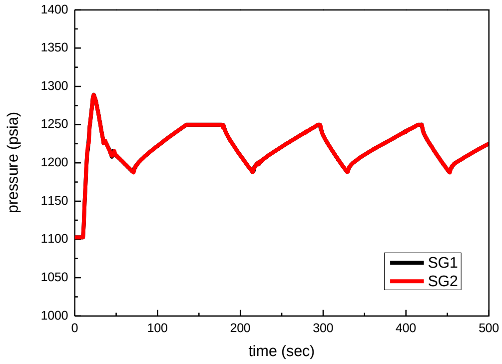

Fig. 6. SG Dome Pressure for Loss of Load ATWS

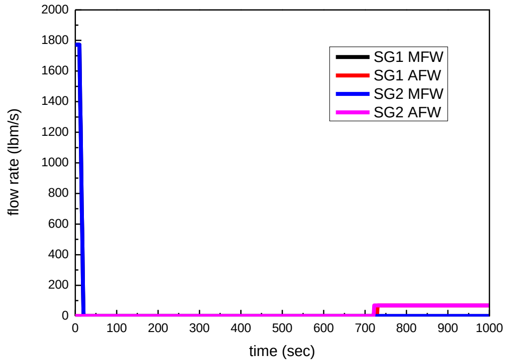

Fig. 9. Feedwater Flow for Loss of Load ATWS

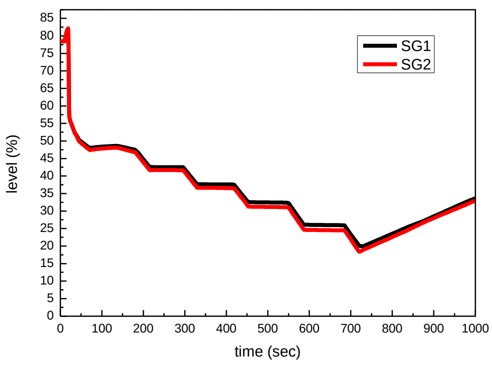

Fig. 7. SG Water Level for Loss of Load ATWS

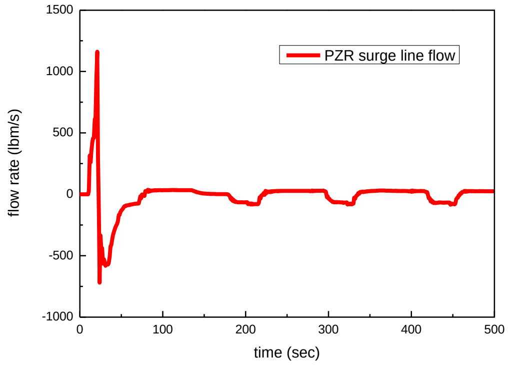

Fig. 10. Pressurzier Surge Line Flow for Loss of Load ATWS

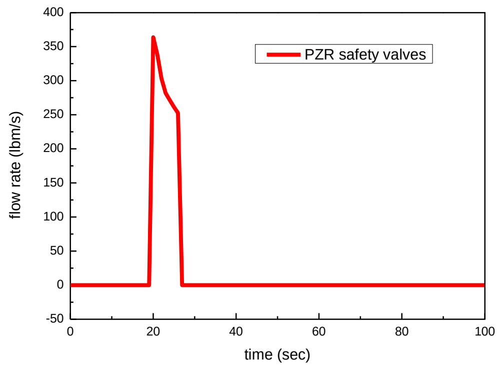

Fig. 11. PZR. Safety Valve Flow for Loss of Load ATWS

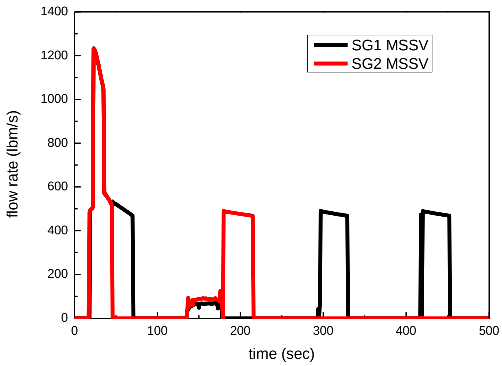

Fig.12. MSSV Steam Flow for Loss of Load ATWS

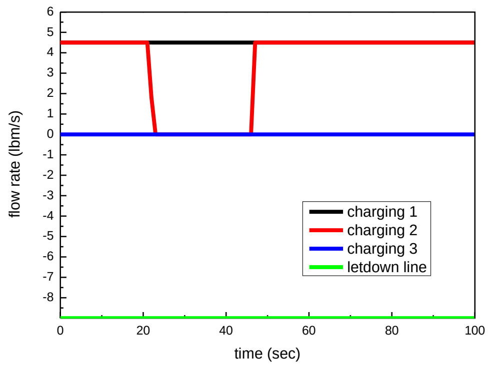

Fig. 13. Charging and letdown Flow for Loss of Load ATWS

2.5 Loss of Feedwater results

The peak RCS and secondary pressure for the ATWS LOFW are 2556 and 1250psia, respectively. The DSS occurs at 1.15 seconds. The DAFAS occurs at 45.0 seconds. The pressurizer did not go solid. See Table V for a sequence of events, and Fig. 14~Fig. 26 for the plots of key output parameters.

Table V: Sequence of Events for Loss of Load ATWS

Time, seconds	Event	Setpoint or Value
0.0	Begin Steady State Run	
10.0	Main Feed Ramp down	
20.0	Main Feedwater Isolated	
37.0	Steam Dump Valves Open	1085 psia
58.2	High PZR. Pressure Alarm	2410 psia
59.3	DSS High Pressure Trip	
59.3	PSVs Open	2500 psia
59.3	Max. RCS Pressure Occurs	2556 psia
60.0	DAFAS Actuates	WR 22.2 %
61.0	Turb. Steam Flow Isolated	
61.1	CEAS Begin to Insert	
68.0	Max. Pressurizer Level	77.3 %
68.8	PSVs Close	2040 psia
105.0	AFW Actuated	
120.6	SIAS Actuation	1762 psia
163.3	MSIS Actuation	885.5 psia
163.3	MSIV Close	
169.0	AFW Reaches SG	
217.0	Steam Dump Valves Close	
2703.0	MSSVs Open (Bank 1)	1250 psia
2704.0	MSSVs Close (Bank 1)	1187.5 psia
3100.0	Max. SG Dome Pressure	1250.3 psia
3132.0	Stabilized State	

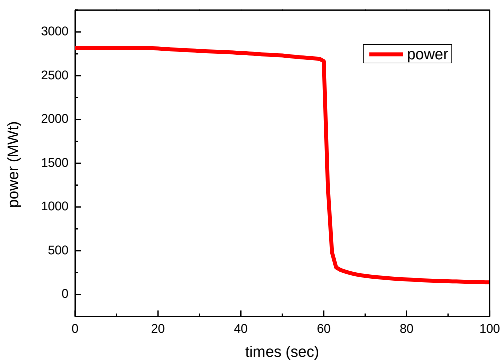

Fig. 14. Nuclear Power for Loss of Feedwater ATWS

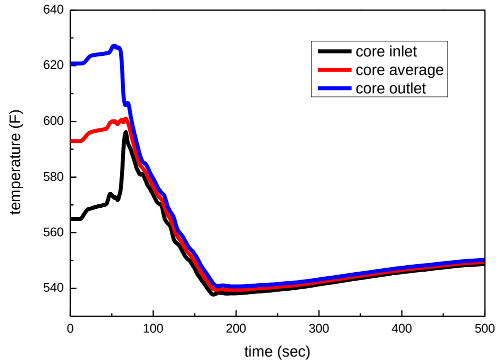

Fig. 15. RCS Temperature for Loss of Feedwater ATWS

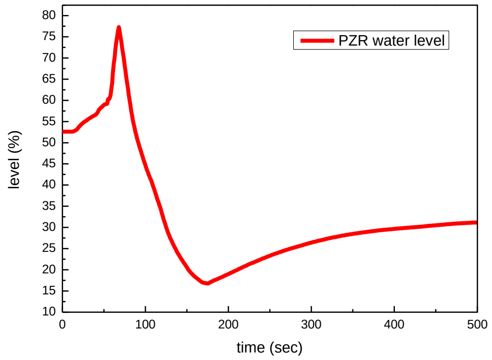

Fig. 18. PZR. Liquid Level for Loss of Feedwater ATWS

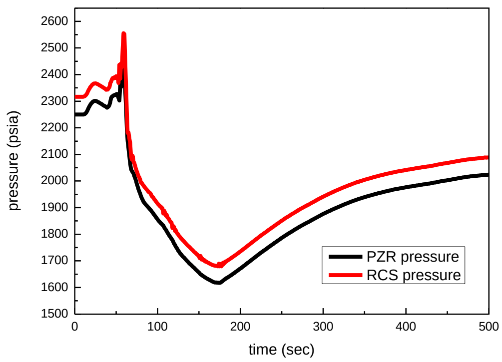

Fig. 16. Primary Pressure for Loss of Feedwater ATWS

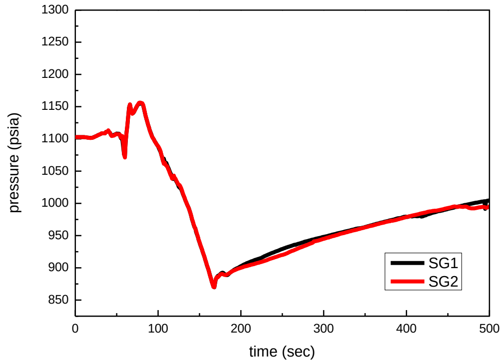

Fig. 19. SG Dome Pressure for Loss of Feedwater ATWS

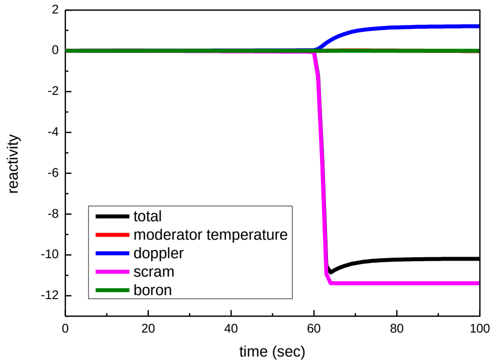

Fig. 17. Reactivity for Loss of Feedwater ATWS

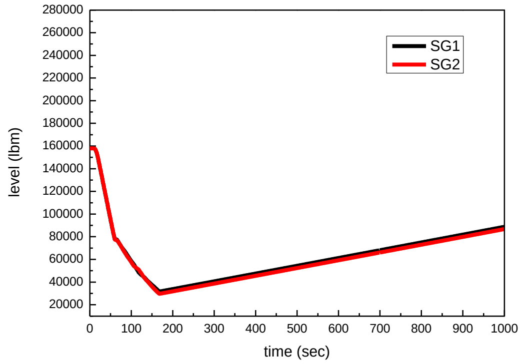

Fig. 20. SG Water Level for Loss of Feedwater ATWS

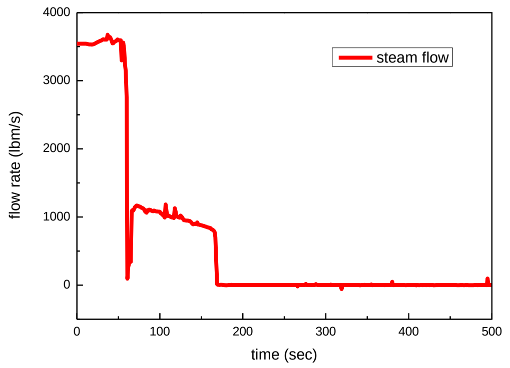

Fig. 21. Steam Flow for Loss of Feedwater ATWS

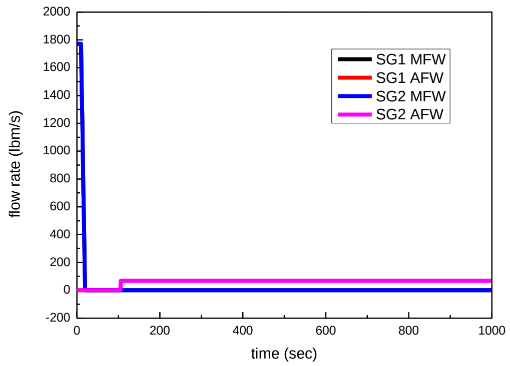

Fig. 22. Feedwater Flow for Loss of Feedwater ATWS

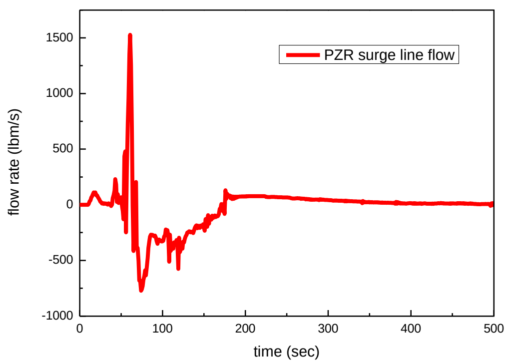

Fig. 23. PZR. Surge Line Flow for Loss of Feedwater ATWS

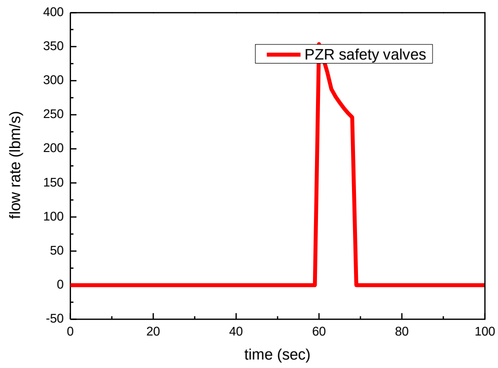

Fig. 24. PZR. Safety Valves Flow for Loss of Feedwater ATWS

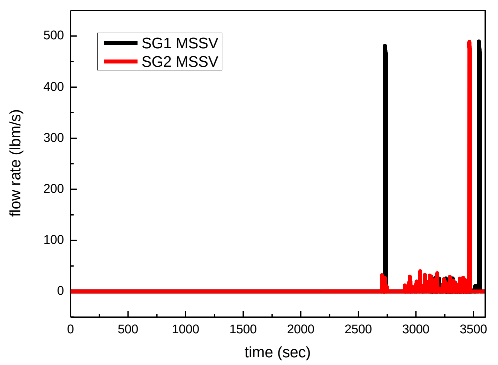

Fig. 25. MSSV Steam Flow for Loss of Feedwater ATWS

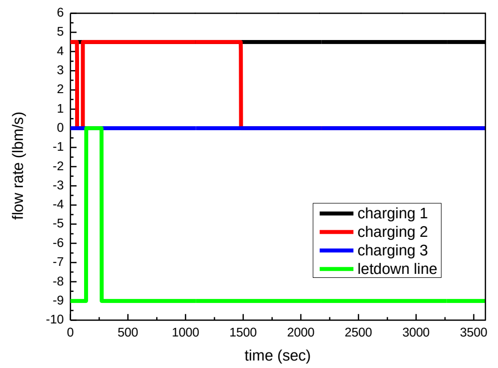

Fig. 26. Charging and Letdown Flow for Loss of Feedwater ATWS

3. Conclusions

This study includes results of Loss of Load and Loss of Feedwater ATWS. The LOL case results in a faster reactor trip than the LOFW since the LOFW does not have the turbine trip at time zero. Hence the primary system heatup rate is faster and results in quicker reactor trip on the DSS. In addition the LOFW event has the SBCS available and as secondary pressure increase, the steam releases from the SBCS valves provide extra cooling to the secondary system, which also cools the primary system. This additional cooling also delays the DSS trip. For the LOFW event, both the turbine and SBCS are providing additional cooling, hence the primary and secondary system heatups are slower and lower. Thus the RCS and steam generator pressure are higher for the LOL event than the LOFW event. The LOL also has a slower decrease in SG water level than the LOFW event. This is due to loss of condenser vacuum that trips and isolates the turbine and renders the SBCS unavailable for the LOL event. Hence the secondary cooling for the LOL event is due to the steam releases from the MSSVs; whereas the LOFW turbine remains online until a DTT occurs on the DSS. Also the SBCS is available because the condenser is available. Thus the LOFW has a faster decrease and a lower SG level. Due to the slower decrease in SG level, the LOL does not actuate the DAFAS until approximately 700 seconds.

REFERENCES

[1] N0291-FS-DD012, DDS 1, Rev. 04, “Fluid System and Component Engineering Design Data for Plant Safety, Containment and Performance Analysis of Ulchin Nuclear Power Plant Uints 3 and 4”, May 1997.
[2] N0291-IC-DD560, DDS-1, Rev. 02, “Design Data for the Safety analysis for Ulchin Nuclear Power Plant Uints 3 and 4” November 1994.
[3] NUREG-0460, “Anticipated Transients Without SCRAM for Light Water Reactors,” April 1978.
[4] U34RSG-ESD-12002, Rev. 00, “Thermal Hydraulic Design Data Required for Plant Safety Performance and Containment Analysis”
[5] U34RSG-FRD-12002, Rev. 00, “Fuel Rod Design Data for Non-LOCA safety analysis”
[6] U34RSG-NDR-12012, Rev. 00, “Nuclear Design Data for the Analysis for U34RSG Boron Dilution Accident(BDA) & Inadvertent Start-up of a RCP(ISRCP)”