Preliminary Assessment for the Mitigative Effectiveness of External Injection during Extended SBO

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1. Introduction

The NRC performed the state-of-the-art reactor consequence analyses (SOARCA) project to develop best estimates of the offsite consequences for potential severe reactor accidents for two pilot plants: the Peach Bottom Atomic Power Station and the Surry Power Station [1]. The short-term station blackout (STSBO) and long-term station blackout (LTSBO) were identified as one of major groups of accident scenarios for analysis. Both types of SBOs involve a loss of all alternating current (AC) power.

SOARCA-like analyses, which were limited to accident progression except offsite consequences, were performed for OPR-1000 PWR. This paper illustrates the preliminary assessment for the mitigative effectiveness of external cooling water injection strategies using fire trucks during the potential extended station blackout accident

2. Analysis Methodology

The analyses consider several types of mitigation measures, including those specified in emergency operating procedures (EOPs), severe accident management guidelines (SAMGs), and the additional equipment and strategies required by the national actions taken in Korea after Fukushima accident. One of the post-Fukushima actions to cope with a station blackout accident is to supply makeup water using fire trucks into the steam generator or the reactor coolant system.

The mitigative measures for the secondary heat removal during SBO accident are atmospheric dump valves (ADV) and fire trucks. Meanwhile, the mitigative measures for the water injection into a reactor coolant system (RCS) are safety depressurization systems (SDS) and fire trucks.

For the simulation of an SBO, all the emergency core cooling (ECC) systems, auxiliary feedwater (AFW) systems except for the turbine driven pump (TDP), and the containment spray are assumed to be inoperable. The STSBO also involves the loss of turbine-driven auxiliary feed water (TD-AFW) systems through loss of direct current (DC) control power or loss of the condensate storage tank and therefore proceeds to core damage more rapidly. In the LTSBO, the secondary heat removal using atmospheric dump valves (ADV) and TD-AFW is assumed to be available during 4 hours initially with battery power.

The analyses were performed with MAAP computer code version 5.02. The MAAP code is a system level computer code capable of performing integral analyses of potential severe accident progressions in nuclear power plants, whose main purpose is to support a level 2 probabilistic safety assessment or severe accident management strategy developments. The code allows operator interventions and incorporates these in a flexible manner, permitting the user to model operator behavior in a general way. The Korean standardized nuclear power plant, the OPR-1000, has been selected as a reference plant for this analysis.

3. Analysis Results

3.1 Results of Short-term SBO

For the unmitigated STSBO, core uncovery may begin at about 2 hours, and reactor vessel failure begins at roughly 7 hours. In this case, hot-leg ruptures at about 3.4 hours and the inventory of safety injection tank is injected as soon as the hot-leg has ruptured. The assumptions of cases and calculation results of the timing of key events for the SG injection and the RCS injection using fire trucks are summarized in Table 1 and Table 2, respectively.

3.2 Results of Long-term SBO

For the unmitigated LTSBO, core uncovery may begin at about 10.2 hours, and reactor vessel failure begins at roughly 16.9 hours. In this case, hot-leg ruptures at about 12.7 hours and the inventory of safety injection tank is injected as soon as the hot-leg has ruptured. The assumptions of cases and calculation results of the timing of key events for the SG injection and the RCS injection are summarized in Table 3 and Table 4, respectively.

REFERENCES

[1] USNRC, “State-of-the-Art Reactor Consequence Analyses (SOARCA) Report”, NUREG-1935, (November, 2012).

Table 1: Analysis results for the case of SG injection using fire truck in short-term SBO

Sequence ID	Assumption		Calculation Results (Event Summary, hours)								
	ADV open										
	# of ADV	Opening time	PSV open	ADV opening time	SG makeup	Core uncovery	Core melt	Corium relocation into LH	SIT injection	RV failure	Hot leg rupture
STU-base	N/A	N/A	1.07	N/A	N/A	1.99	3.16	5.45	3.43	7.06	3.42
STM1-1ADV-PSV05	1	PSV open	1.07	1.16	1.18	no uncovery	no melt	no relocation	10.33	no failure	no rupture
STM1-1ADV-PSV60	1	PSV open +1 hr	1.07	2.07	2.10	2.00	no melt	no relocation	8.41	no failure	no rupture
STM1-1ADV-PSV120	1	PSV open +2 hr	1.07	3.07	3.10	2.00	3.13	6.49	3.50	7.96	3.49
STM1-2ADV-PSV120	2	PSV open +2 hr	1.07	3.07	3.10	2.00	3.13	7.14	3.90	9.27	3.90

Table 2: Analysis results for the case of RCS injection using fire truck in short-term SBO

Sequence ID	Assumption		Calculation Results (Event Summary, hours)								
	SDS open										
	# of SDS	Opening time	PSV opening	SDS opening	Core uncovery	Core melt start	Hot leg rupture	SIT injection	RCS makeup start	Corium relocation into LH	RV failure
STU-base	N/A	N/A	1.07	N/A	1.99	3.16	3.42	3.43	N/A	5.45	7.06
STM2-1SDS00	1	PSV open		1.10	1.74	2.23	no rupture	2.21	7.43	6.61	no failure
STM2-2SDS60	2	PSV open +1 hr		2.10	2.00	no melt	no rupture	2.31	5.94	no relocation	no failure
STM2-2SDS120	2	PSV open +2 hr		3.10	2.00	3.04	no rupture	3.26	6.61	6.79	no failure
STM2-2SDS180	2	PSV open +3 hr		4.10	2.00	3.04	3.76	3.77	3.78	no relocation	no failure

Table 3: Analysis results for the case of SG injection using fire truck in long-term SBO

Sequence ID	Assumption		Calculation Results (Event Summary, hours)									
	ADV open											
	# of ADV	Opening time	PSV open	ADV opening	SG makeup	Core uncovery	Core melt start	Hot leg rupture	SIT injection	Corium Relocation into LH	RV failure	CTMT failure
LTU-base	N/A	N/A	9.6	N/A	N/A	10.2	12.3	12.7	12.7	14.7	16.9	109.3
LTM1-1ADV-PSV05	1	PSV open	9.6	9.7	9.8	no uncovery	no melt	no rupture	10.8	no relocation	no failure	no failure
LTM1-1ADV-PSV60	1	PSV open + 1 hr	9.6	10.6	10.1	10.3	no melt	no rupture	16.4	no relocation	no failure	No failure
LTM1-1ADV-PSV180	1	PSV open + 3 hr	9.6	12.6	12.7	10.3	12.4	12.7	12.7	16.7	18.5	118.6

Table 4: Analysis results for the case of RCS injection using fire truck in long-term SBO

Sequence ID			Calculation Results (Event Summary, second)								
	SDS open										
	# of SDS	Opening time	PSV opening	SDS opening	Core uncovery	Core melt start	Hot leg rupture	SIT injection	RCS makeup start	Corium relocation into LH	RV failure
LTU-base	N/A	N/A	9.6	N/A	10.4	12.5	12.7	12.7	N/A	15.3	17.0
LTM2-1SDS00	1	PSV open	9.6	9.6	10.0	16.1	no rupture	10.4	18.6	106.0	no failure
LTM2-2SDS120	2	PSV open +2 hrs	9.6	11.6	10.4	no melt	no rupture	11.8	15.4	no relocation	no failure
LTM2-2SDS180	2	PSV open +3 hrs	9.6	12.6	10.4	12.5	no rupture	12.8	17.7	no relocation	no failure
LTM2-2SDS300	2	PSV open +5 hrs	9.6	14.6	10.4	12.5	12.7	12.7	14.7	no relocation	no failure