Total Loss of Feedwater Analysis of Power Uprated Kori 3&4

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1. Introduction

The TLOFW event is a beyond design basis accident resulting from a hypothetical loss of both main feedwater and auxiliary feedwater to the steam generators. The previous studies [1,2] have concluded that the Feed and Bleed (F&B) can be a viable alternate means of decay heat removal, but successful F&B operation is contingent on the existence and use of procedures, as well as on the specific plant design. In Optimized Power Reactor 1000 (OPR1000), Safety Depressurization System (SDS) to mitigate the event of Total Loss of Feedwater (TLOFW) is adopted. The acceptance criteria applied in the design of the SDS is that the core should not be uncovered by bleed and feed (B&F) operation. The criterion of the core coverage applied in the OPR1000 is that core mixture level should be maintained with at least two feet margin above the core top.

However, there is no SDS in Kori 3&4, which has three safety grade Power Operated Relief Valves (PORVs). Korea Hydro & Nuclear Power Co. Ltd (KHNP) analyzed the TLOFW analysis of Kori 3&4 for Periodic Safety Review [3] and the results showed that core uncovery can be prevented when operators open two out of three PORVs before the steam generators are dried out. The analysis concluded that core mixture level would be sufficiently maintained above the core if void fraction of core top is maintained below 30 %.

The power uprate program will be implemented for Kori 3&4. These plants were designed by Westinghouse Electric Company (WEC) and the licensed core power is 2775 MWt. The target power of power uprate is approximately 4.5% increase for each unit (2900 MWt). This paper focused on the evaluation of the capability of decay heat removal during TLOFW accident for power uprated Kori 3&4.

2. Analysis Methodology

The major assumptions used in the analysis of the TLOFW are steady state full power operating condition and reactor coolant pumps (RCPs) trip at 10 minutes after the reactor trip. Table 1 shows the initial conditions of major plant parameters used in this analysis for the power uprated Kori 3&4 using RELAP5/MOD3 [4]. In TLOFW analysis, Henry-Fauske critical flow model is used for two phases. To evaluate the mass inventory in the core, the mixture level is calculated by a combination of flow regime and void fraction.

Table 1. Initial Conditions for TLOFW Analysis

Parameter	Design	Calculation
Core power, MWt	2900	2900
Pressurizer pressure, MPa (psia)	15.51 (2250)	15.51 (2250)
Core inlet temperature, K (^{o}F)	562.59 (553)	562.00 (551.9)
Flow rate per one loop, kg/s (lb/s)	4447.7 (9806)	4447.7 (9806)
Core bypass flow rate, kg/s (lb/s)	893.99 (1971)	893.39 (1970)
Pressurizer level, m (ft)	6.93 (22.7)	6.88 (22.6)
Secondary pressure, MPa (psia)	6.23 (904)	6.27 (909.3)
Feed water flow rate, kg/s (lb/s)	543.05 (1197)	543.05 (1197)
Steam flow rate, (kg/s (lb/s)	543.05 (1197)	543.05 (1197)
steam generator level, m (ft)	12.75 (41.83)	12.72 (41.73)
Steam generator circulation ratio	3.7	3.63

3. Analysis Results

The sequence of events for before and after power uprate is provided in Table 2. The pressure and core level for power uprated Kori 3&4 are in Figures 1 and 2 for the operator recovery action times of 5 and 20 minutes.

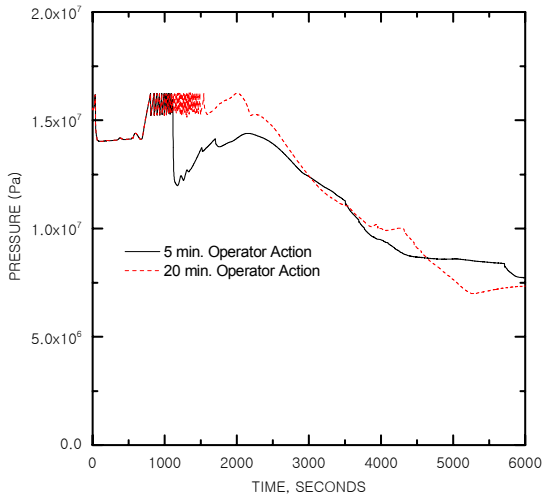

Figure 1. Pressurizer Pressure (Bleed Path Open at 5 and 20 minutes after SG Dryout)

The transient is initiated by the assumed instantaneous loss of main feedwater and auxiliary feedwater. Following the total loss of feedwater, a reactor trip occurs

at 30.86 seconds due to low steam generator level. The RCS pressure falls following reactor trip due to the decreased heat input from the core. After a short time period, the RCS pressure starts to rise in response to the decreased heat removal capability of the steam generators due to the loss of secondary side liquid inventory. When both steam generators dry out (812.1 seconds), primary to secondary heat transfer will be terminated. This causes the primary side heat up and acceleration of volumetric expansion. The RCS pressurization stops when the PORVs opening set point (2364.7 psia). Steam and liquid discharge through the PORVs. For no bleed path case, continued depletion of RCS inventory results in the beginning of core uncovery at 2514 seconds.

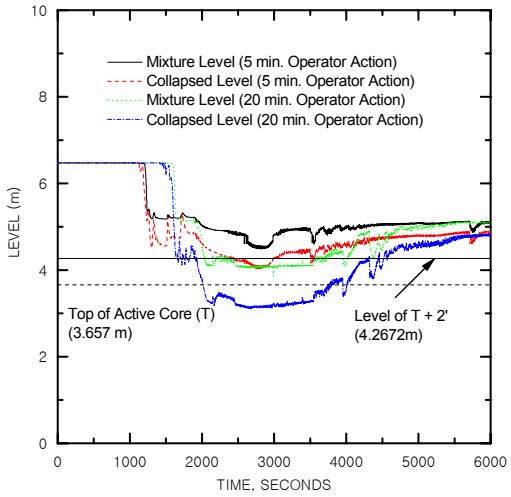

Figure 2. Core Level (Bleed Path Open at 5 and 20 minutes after SG Dryout)

The pressurizer pressure rapidly falls following the manual opening of PORVs as a bleed path. This initiates sufficient High Head Safety Injection (HHSI) inflow to the RCS. The pressure then rises when the bleed valve discharge changes from steam to low quality two phase. Eventually, the PORVs discharge becomes high quality two phase and the RCS depressurization resumes. The continued decrease in RCS pressure results in increased HHSI flow which causes the increase of RCS inventory. The minimum mixture level is 4.49 m at about 2750 seconds, which has two feet margin (4.2672 m) above core top.

The minimum mixture level for recovery operator action at 20 minutes after steam generator dryout is 3.84 m at about 2990 seconds as shown in Table 2. This mixture level is above the core top, even though the level has no two feet margin above core top.

Table 2. Event Sequences of TLOFW for KORI 3&4

Case	Analysis Result before Power Uprate [3]	No Bleed Path	Operator Action at 5 min. after SG dryout	Operator Action at 20 min. after SG dryout
No. of PORVs	2	-	2	2
No. of HHSIs	2	-	2	2
Event	Time (sec)			
Reactor Trip	30.7	30.86	30.86	30.86
RCP trip, manual	600.0	630.86	630.86	630.86
SG dryout	890.0	812.1	812.1	812.1
PORVs open	900	N/A	1112.1	2012.1
HHSI start	936.8	N/A	1139.1	2039.1
Core Uncovery begins	-	2514	-	-
Min. Core Level* occurs at, sec	-	-	4.49 m 2750	3.84 m 2990

* Core top is 3.6576 m. (Core top with 2 ft margin is 4.2602 m)

4. Conclusion

The TLOFW analysis was carried out to evaluate the capability of decay heat removal for power uprated Kori 3&4. The results of analysis show that the PORVs capacity is sufficient to keep the core covered with 2 feet margin if the operator opens two PORVs at 5 minutes after the steam generator dryout. The results of analysis also show that the PORVs capacity is sufficient to keep the core covered without 2 feet margin if the operator opens two PORVs at 20 minutes after the steam generator dryout.

ACKNOWLEDGMENTS

This project has been carried out under the Electric Power Industry Technology Development Program supported by the Korean Ministry of Commerce, Industry and Energy.

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