Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Development and Test Results of the Realtime Severe Accident Model 5 (RSAM5) based on the MAAP5 For the Kori-1 Simulator

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1. Introduction

The Real Time Severe Accident Model (RSAM) in the Kori simulator employs the standard MAAP 5.01.1101 code [1] (which is defined as MAAP 5.01) plus several statically linked libraries that interface with the simulator environment. The physical phenomena that can be envisioned inside the reactor vessel, the reactor coolant system (RCS), and the containment during severe accidents are comprehensively modeled by the MAAP5 code. The MAAP5 code has been known to be a reliable tool for understanding the sequence of events that occur during severe LWR accidents, evaluating the consequences of the failure of emergency systems, assessing the effects of operator interventions, and investigating the influence of design features of the RCS, containment, and safety systems on the accident consequences.

The purpose of this paper is to describe the modeling of the Kori Unit 1 nuclear plant with the MAAP5 code and major outputs in the event of the SBO, SBO + SGTR, SBO + LBLOCA.

1. Model Description

Kori Unit 1 is a 2-loop Westinghouse pressurized water reactor in Gijang, Busan, South Korea. It is modeled in the MAAP5 parameter file that has been developed from the existing MAAP4 parameter file, Kori 1 FSAR, existing Kori 1 RELAP input data, and reference replacement steam generator data. Kori 1 containment nodalization is shown in **Error! Reference source not found.** and **Error! Reference source not found.**. The Kori 1 MAAP5 parameter file was developed from the existing MAAP4 parameter file in a customary way

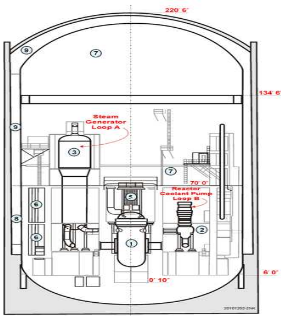

Fig.1 K1 CTMT Nodalization (Cross-section)

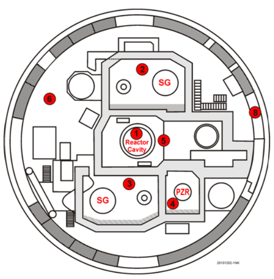

Fig.2 K1 CTMT Nodalization (44ft Elevation)

2. Results

The Kori 1 MAAP5 parameter file was tested by running several sample sequences, and the results are discussed in the following sections. The following sequences were run:

- Steady State (SS)
- Large LOCA (LLOCA)
- Station Blackout (TMLB)

Except for the steady-state, these sequences are defined as straightforward severe accident sequences without any complexity of the emergency operating procedures. In addition, the LLOCA, and TMLB sequences were run with recovery actions. Dose and activity concentrations are calculated for these accidents, and those values may be viewed as “order of magnitude” figures of merit because of the significant variation associated with the details of sequence definitions, the EOP, operator interventions, and the assumption on the containment leakage rate.

2-1. Steady State

A steady state (ss*.*) null transient sequence was analyzed to demonstrate stable primary system and containment conditions when no accident conditions are present. Steady system performance is a key indicator of proper initialization and consistent model definition. As shown in Figure 3 to 4, the primary system core water temperature (TWCR) and pressure (PPS) remain fairly constant at their initial values.

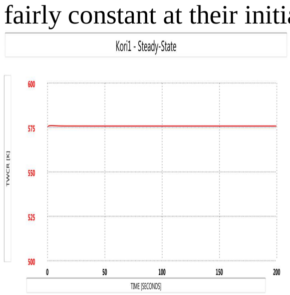

Fig.3 TWCR

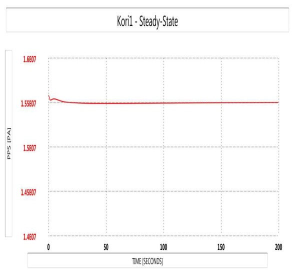

Fig.4 PPS

2-2. Large LOCA

A large LOCA sequence with a double-ended guillotine cold leg break, containment fan coolers disabled, and a failed transfer to recirculation (LLOCA.*) was performed for the Kori 1 MAAP 5 Parameter File. As the sequence begins, primary system rapidly depressurizes, causing ESF initiation. As the RWST is depleted, all injection stops, and the sequence goes to severe accident. Key event timings for this sequence are summarized in **Error! Reference source not found.**.

<Table.1> K1 LLOCA Key Event Timing

Core uncovery	1.52 s
Hot leg creep rupture	N/A
First relocation of core material to lower plenum	8762 s
Vessel failure	14011 s
Containment failure	N/A

Several parameters for this sequence are shown in Figure 5 to Figure 6.

As the transient begins and the primary system is depressurizing, the primary system void fraction increases. Water flow rate out the break decreases, allowing more steam to flow out the break. Eventually, the break flow equilibrates to match the RWST injection flow. Due to break flow and containment spray operation, lower compartment water level increases.

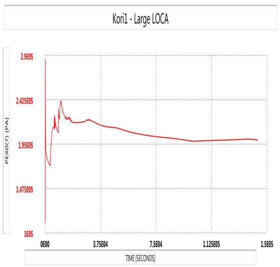

Fig.5 PEX0(7)

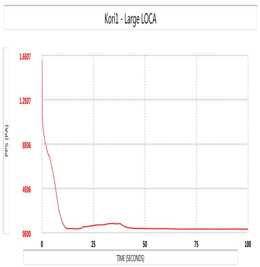

Fig.6 PPS

Once the RWST is depleted, injection is terminated and the fuel begins to heat up and melt. The core relocates to the lower plenum and eventually fails the vessel. The corium soon begins to ablate the concrete in the reactor cavity. Containment pressure is relatively steady for the remainder of this sequence, similar to station blackout with hot leg creep rupture.

2-3. Station Blackout

A station blackout (SBO) sequence with seal LOCAs 2700 s into the sequence (TMLB.*) was performed for the Kori 1 MAAP 5 Parameter File. Following blackout initiation, the vessel pressure increases as the primary system and steam generator water inventories are boiled off. The RCS pressure reaches the set-points of pressurizer safety valves, and oscillates between the pressurizer safety dead-bands. RCP seal leaks contribute to primary coolant loss and depressurization. This condition leads to core uncovery, fuel heatup, and eventually hot leg creep rupture. At the time of hot leg creep rupture, accumulators inject, delaying the inevitable reactor vessel failure. **Error! Reference source not found.**2 summarizes these key event timings.

<Table.2> K1 SBO Key Event Timing

Core uncovery	6148 s
Hot leg creep rupture	10651 s
First relocation of core material to lower plenum	17151 s
Vessel failure	21424 s
Containment failure	N/A

Since the primary system water level is the boiled-up level, a brief spike is shown around 17,000 s when core begins relocating to the lower plenum.

Containment pressure is steady until the RCP seal LOCA. Then it begins to gradually rise to a relatively steady point. Next, the rate of containment pressurization is accelerated by quench tank rupture disk failure. The containment pressure gradually begins to level out until the spike caused by hot leg creep rupture. Eventually, containment pressure begins to decrease, due to effects of containment heat sinks and completion of the primary system blow-down. This is interrupted by another spike caused by the steaming due to core relocation to the RPV lower plenum. Finally, after vessel failure, the corium drops to the reactor cavity, quickly evaporating the minute amount of water there. It then begins to ablate the surrounding concrete, and the resulting gasses released into the containment cause a steady pressure rise for the remainder of this sequence.

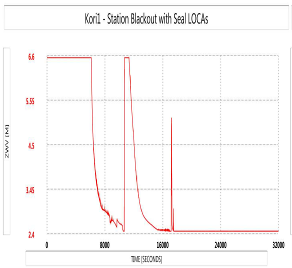

Fig.7 ZWV

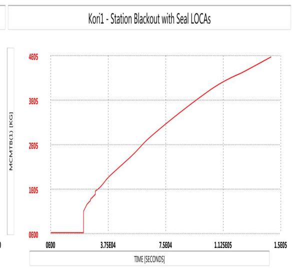

Fig.8 MCMTB(1)

3. CONCLUSIONS

A working MAAP 5.01 parameter file has been developed and tested. Several sequences were executed with this parameter file. The MAAP 5.01 code was modified to interface with the simulator MAAP Interface module. The resulting RSAM code was verified to execute representative sequences correctly in the simulator environment, both as a standalone module, and also after a switch from the RELAP-RT module after plant conditions are near the boundaries of the RELAP-RT code.

REFERENCES

[1] Fauske & Associates, LLC, 2011, "*MAAP5: Modular Accident Analysis Program for LWR Power Plants, Transmittal Document for MAAP5 Code Revision MAAP5.0.1. FAI11-1161*", November.