Analysis of Total Loss of Secondary Heat Removal for SMART

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1. Introduction

Total Loss of Secondary Heat Removal (TLOSHR) is initiated by total loss of feedwater supply from feedwater supply system and passive residual heat removal system (PRHRS). Thus, heat removal through the secondary system is eliminated. The event is a very low probability beyond design basis event for SMART.

SMART have a Safety Depressurization System (SDS) to mitigate the consequence of TLOSHR. The SDS causes a rapid depressurization of reactor coolant system (RCS) enough to initiate safety injection. Feed and bleed (F&B) operation is available with safety injection and SDS.

The SDS bleed capability is assessed by MARS code. Also thermal hydraulic behavior of TLOSHR is verified with the safety analysis.

2. Safety Depressurization System

2.1. General Description

The SMART SDS is a designated safety-grade system that is not required to facilitate a safety function during both normal operation and design basis accidents. The SDS can be utilized for the severe accident condition requiring a rapid depressurization of the RCS.

The SMART SDS consists of two separate lines connected to the top head of the pressurizer, and the flow through each line discharges to the reactor building atmosphere through a rupture disk. Each bleed path includes an isolation valve and a control valve in series. In the feed and bleed operation, the cold water is fed to RCS via the SIP and high energy coolant is bled from RCS via the SDS bleed valves.

2.2. Acceptance Criteria

According to the licensing requirements of Ref. [1], the acceptance criteria for satisfactory feed and bleed operation is that the two-phase mixture level in the core does not fall below the top of the active core. With respect to the SDS bleed flow capacity, two SDS design performance criteria have been established.

(1) A single SDS bleed path, in conjunction with two of four Safety Injection Pumps (SIP), shall have sufficient capacity to prevent core uncovery with two feet margin following a TLOFW if one bleed path is opened at the time of pressurizer safety valves (PSVs) lift.

(2) Both bleed paths, in conjunction with four SIPs, shall have sufficient capacity to prevent core uncovery with two feet margin following a TLOFW if F&B initiation is delayed up to 30 minutes from the time of PSVs lift.

3. Analysis Methodology

A best-estimate analysis is acceptable for beyond DBA analysis. So, realistic modeling and safety analysis code are utilized for the analysis.

3.1. Analysis Code

The analysis of the thermo-hydraulic behavior until the reactor trip was performed by the TASS/SMR-S code [2], and the reactor trip time obtained from the TASS/SMR-S calculation was used as an input for the MARS [3] analysis. Fig. 1 shows the SMART nodalization used for MARS calculation.

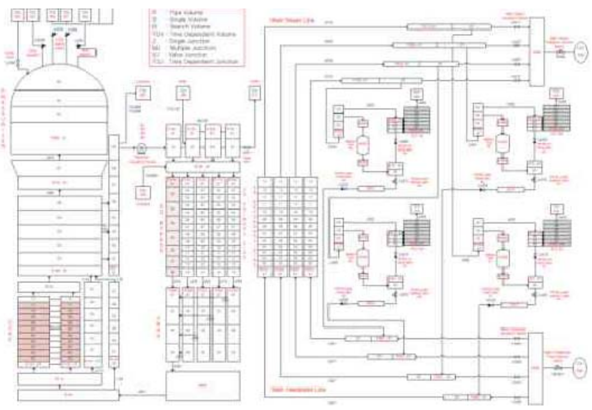

Fig. 1 SMART Nodalization for MARS Calculation

3.2. Analysis Cases

Three cases of analyses are performed to assess the SDS bleed capability of SMART. One of them is based on operation without operator action such as a SDS operation. And rest of them are originated from the acceptance criteria. So, TLOSHR with and without a single failure cases are analyzed.

3.3. Initial Conditions and Assumptions

The system parameters and initial conditions are selected as realistic values at normal operation. And assumptions given below are used for analysis.

(1) Nominal operating power rate
(2) Instantaneous and complete loss of feed water to all SGs

(3) No PRHRS actuation
(4) No letdown and charging system operation
(5) No pressurizer heater operation
(6) RCP trip, 10 minutes after reactor trip
(7) 1973 ANS standard decay heat curve

4. Analysis Results

4.1. TLOSHR without SDS Operation

Upon the stop of the feedwater supply, the RCS pressure increased rapidly. So, PSV opened to protect the RCS integrity. But RCS pressure increased again, because of loss of heat removal. The PSV opened repeatedly and RCS level decreased continuously.

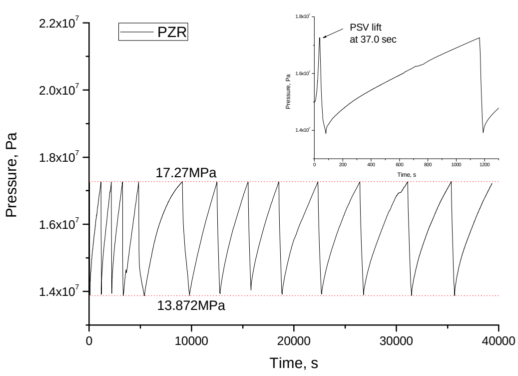

Fig. 2 RCS Pressure for TLOSHR without SDS operation

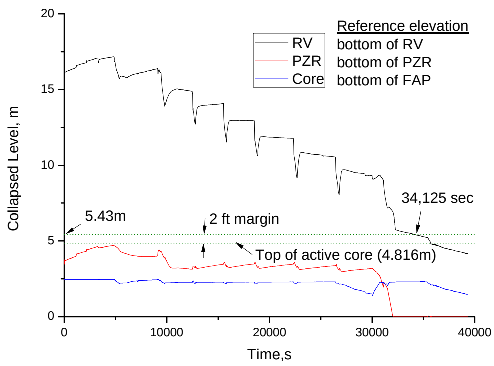

Fig. 3 Reactor Coolant Level for TLOSHR without SDS operation

4.2. TLOSHR with single failure

At 0 second, the feedwater supply was eliminated and then PSV was opened to protect RCS integrity. Simultaneous with the PSV opening, the operator opened one bleed path.

With PSV opening and SDS operation, the RCS pressure decreased enough to initiates the safety injection system. With the one train of SDS and two trains of safety injection system, feed and bleed operation is established. The discharging flow decreased as the RCS depressurized. At last, the reactor coolant level of RCS is recovered as shown in Fig. 4.

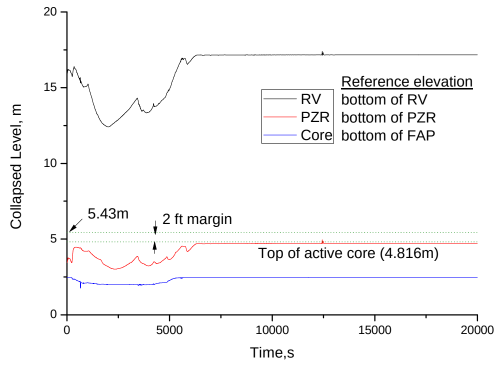

Fig. 4 Reactor Coolant Level for TLOSHR with Single Failure

4.3. TLOSHR without single failure

At 0 second, the feedwater supply was eliminated and then PSV was opened to protect RCS integrity. After 30 minutes from the PSV opening, the operator opened both bleed paths.

Thermo-hydraulic behavior of RCS is almost similar to those of previous cases, but the minimum reactor coolant water level is lower than the single failure case because of delayed SDS actuation. the reactor coolant level of RCS is recovered as shown in Fig. 5.

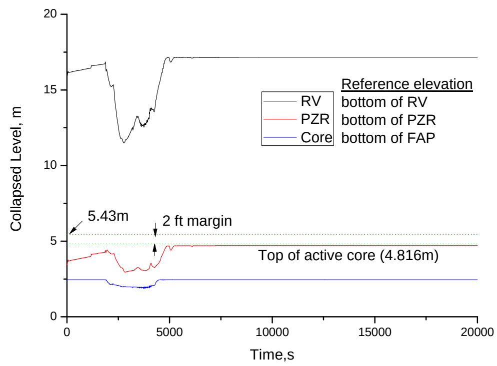

Fig. 5 Reactor Coolant Level for TLOSHR without Single Failure

5. Conclusion

The best estimate analysis of TLOSHR was performed using MASR code. The feed and bleed operation using the SDS and Safety Injection System meets the acceptance criteria with a great margin.

REFERENCES

[1] Korea Institute of Nuclear Safety, “Regulatory Guidance for PWRs, Appendix 19-1”, KINS, 2009.

[2] Korea Atomic Energy Research Institute, “TASS/SMR-S Technical Report Vol.1”, 911-TH464-001, KAERI, 2010

[3] Korea Atomic Energy Research Institute, "MARS3.0 Code Manual Input Requirements," KAERI/TR-2811/2004, KAERI, 2004