Preliminary Analysis for the SMART Over-Pressure Protection

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1. Introduction

A preliminary analysis was performed to evaluate adequacy of overpressure protection and thus verify capacity of pressurizer safety valves for the SMART(System-Integrated Modular Advanced Reactor). Pressure vessel of reactor facility should satisfy the overpressure protection requirements specified in ASME code Section III[1] and SRP 5.2.2[2]. For the overpressure protection of the SMART, there are pressurizer safety valves for RCS, safety relief valves in PRHR(Passive Residual Heat Removal System) for the secondary system, and the PPS(plant protection system).

2. Analysis Method

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2.1 Computer Code

TASS/SMR[3] code developed by KAERI was used to perform analysis of overpressure protection for the SMART. As a thermal-hydraulic system code to simulate RCS, secondary steam/feed water system and PRHR system of the SMART plant, TASS/SMR code has been developed to calculate normal and abnormal conditions as well as the accident conditions.

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2.2 Acceptance Criteria

In accordance with the ASME code section III, SRP 5.2.2 and KEPIC MNB 700 [4], the peak pressure during the pressure transients which mostly pressurize the RCS and SG secondary system should not exceed 110% of the design pressure.

2.3 Design Basis Events

The design basis event used to evaluate capacity of the safety relief valves in commercial loop-type pressurized water reactors was a loss of load event with a delayed reactor trip.[5.6] The transient events which pressurize RCS of the SMART plant include loss of secondary heat removal, loss of primary flow and withdraw of control rod elements at full power. The loss of primary flow was excluded in the analysis since the loss of secondary heat removal events were analyzed based on a loss of offsite power resulting in RCPs trip. As shown in the figure 1, the most high peak pressure occurred in the event of loss of load.

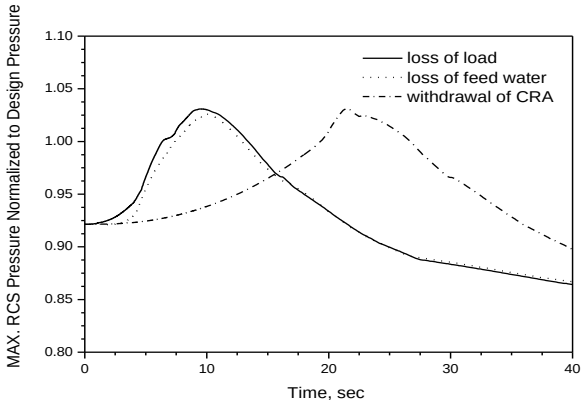

Fig. 1. RCS pressure behavior during various transients.

3. Initial Conditions and Assumptions

3.1 Initial Condition

The ranges of initial conditions for the loss of load event and sensitivity study are as follows;

Primary system and secondary system
- Core Power : 0~103% of 330MWt
- Pressurizer pressure : 14.15 ~ 15.55 MPa
- Pressurizer level : 63.5 ~ 71.5 %
- Core exit temperature : 320.87 ~ 325.13 ^{o}C
- RCS flow rate : 95~115% of 2090 kg/s
- Axial offset : -0.3 < AO < 0.3

To determine a set of initial conditions which mostly pressurize the RCS during a loss of load event, sensitivity analyses were carried out based on the various initial parameters such as RCS flow rate, SG primary inlet temperature, pressurizer level/pressure, and axial power distribution. The initial condition of high RCS flow rate, high SG primary inlet temperature, high pressurizer pressure/level and top skew axial power was found to be the most severe case as a result of the sensitivity studies.

3.2 Assumptions

For the preliminary analysis of the SMART overpressure protection, major assumptions used are as follows;

(1) The reactor power is assumed to be at full power with a level plus 3% uncertainty.
(2) Zero moderator temperature coefficient is used for conservatism.
(3) Most positive fuel temperature coefficient is used.
(4) 17.34 MPa was used for an opening set pressure of pressurizer safety valves. (a total 2% uncertainty is considered).
(5) The reactor trip is assumed to occur with only high pressurizer pressure.
(6) Assuming a single failure, three trains of the PRHRS out of four trains of PRHR system are credited.
(7) The charging flow, letdown flow, pressurizer spray flow are not credited. All control systems are assumed to be in the manual mode.

4. Analysis Results

The rated area of pressurizer safety valves used for the analysis is $1.24e^{-3}m^2$. Figure 2 shows RCS pressure behavior during a loss of load for the rated area of pressurizer safety valves. The peak pressure is below design pressure.

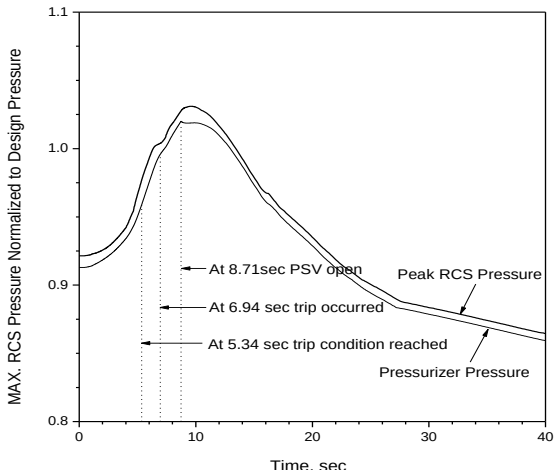

Fig. 2. RCS pressure behavior during loss of load

As shown in figure 3, additional increase of pressurizer in the safety valves area over the rated area has small effect on the decrease of peak pressure occurring during a loss of load event.

The figure 4 shows a behavior of the SG secondary pressure following a loss of load event. The peak pressure is far below the design pressure of the SG secondary system.

5. Conclusions

The results of the SMART overpressure protection analysis showed the RCS and SG secondary system are protected from the overpressure during the loss of load event with a delayed reactor trip in accordance with the ASME code section III and KEPIC code. The peak pressure during the transient was calculated at 17.52 MPa and thus maintained below 110% of the design pressure of 17.0 MPa(18.7 MPa).

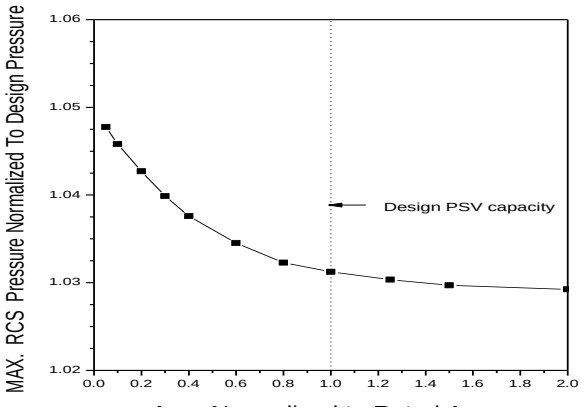

Fig. 3. RCS pressure behavior during loss of load

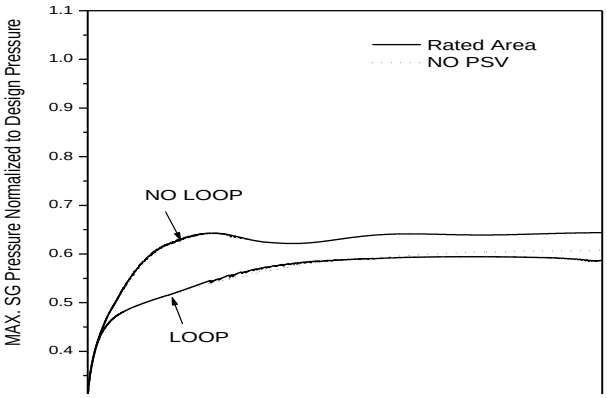

Fig. 4. SG secondary pressure behavior during loss of load

REFERENCES

[1] ASME Boiler and Pressure Vessel Code Section III, NQA-1, 1994.
[2] USNRC SRP 5.2.2, Overpressure Protection, Rev. 02, NUREG-0800 Rev.03, March 2007.
[3] KAERI/TR-3640/2008, TASS/SMR Code Topical Report for SMART Plant
[4] Nuclear 1 Class Equipment Overpressure Protection, KEPIC MNB 7000, 2000.
[5] UCN 3&4 Final Safety Analysis Report
[6] YGN 5&6 Final Safety Analysis Report