Evaluation of the Increase in the POSRV Closing Time for APR1400

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1. Introduction

Pilot Operated Safety Relief Valve (POSRV) is one of major equipment to protect the over-pressurization of Reactor Cooling System (RCS) during design operational transients in accordance with the guidelines set forth in the ASME code Section III [1].

The closing time of POSRV of Advanced Power Reactor 1400 (APR1400) is going to be changed based on the installation test results. The valve test shows that the actual stroking time is longer than the design value.

The effect of the change of the POSRV closing time on the overpressure protection (OP) transient is evaluated. And, a sensitivity study is accomplished for surveying the POSRV closing time which may initiate the safety injection.

For the study, KEPCO E&C Integrated Systems Performance Analysis Code (KISPAC) is used for the simulation of transients.

2. Analysis Methodology

2.1 KISPAC Computer Code

The KISPAC computer code is a best-estimate simulation tool developed to evaluate the Performance Related Design Bases Events (PRDBEs) and is used for overpressure protection and natural circulation cooldown analyses for APR1400.

The KISPAC code uses a detailed node and flow path methodology to model the transient behavior of the fluid systems and components of the NSSS. This code performs a mass, energy, and volume balance in each node and a momentum balance on each flow path. The momentum balance includes the effects of inertia, elevation, and frictional and geometric losses. This ensures that all RCS pressures are correctly predicted. The code contains models for all plant control and protection systems. The modelled NSSS control systems include: Reactor Regulating System (RRS), Pressurizer Pressure and Level Control Systems (PPCS/PLCS), Feedwater Control System (FWCS), Steam Bypass System (SBCS) and Reactor Power Cutback System (RPCS).

2.2 Analyzed Case

The loss of load event, in conjunction with a delayed reactor trip, is chosen for this study. This event is the most severe one among the abnormal operational transients for the overpressure protection analysis required by SRP Section 5.5.2 [2]. The loss of load event assumes a complete loss of secondary heat removal and feedwater flow at the time of event initiation. There are two concerns, the overpressure protection and the SIAS actuation.

2.3 Analysis Method

POSRV closing time change from 0.95 seconds to 1.45 seconds(analysis value is 1.5 seconds) is suggested as the as-built based on the POSRV installation test. Thus an analysis for the evaluation is needed for this change. A sensitivity study is performed to investigate the effects of the POSRV closing time on the initiation of the safety injection actuation signal (SIAS).

3. Initial Condition and Assumption for the Code Simulation

The initial conditions for the code simulation of the loss of load event of APR1400 are given in Table 1.

In the table, a set of the analysis value is used for the overpressure protection (OP) analysis, whereas a set of the sensitivity study (parenthesis value) for the SIAS study.

Table 1. Initial Conditions

Parameters	**Analysis Value (Sensitivity Study Value)**
POSRV Opening Setpoint (psia) POSRV Closing Setpoint (psia) POSRV Opening Time (sec.) **POSRV Closing Time (sec.)**	2519.4 (2470.) 2266. (2148.9) Dead Time: 0.25 Stroking Time: 0.3 **Total Time: 1.5 (1.5 ~ 5.0*)**
Safety Injection Actuation Signal Setpoint (psia)	1810.
Main Steam Safety Valves Opening Setpoint (psia) Closing Setpoint (psia)	 1235.7, 1267.9, 1293.9 1173.9, 1204.5, 1229.2
Thermal Power (%)	102.
Initial Pressurizer water Level (%)	50.
Initial Pressurizer Pressure (psia)	2175. (2250.)
SG water Level (%)	50.

*Range for the sensitivity study

APR1400 POSRVs open with 0.25 seconds of dead time and 0.3 seconds of stroking time after the opening setpoint is reached.

However, POSRV's total closing time is assumed to be changed from 1.5 seconds to 5.0 seconds after the closing setpoint is reached for surveying the acceptable closing time. The nominal design value is used for POSRV opening setpoint (2470 psia) and the SIAS setpoint (1810 psia). The reason is that using nominal design value has the reasonable results compared to the maximum value.

The simulation of the event was initiated at a full power condition but some NSSS control systems (RRS, PPCS, PLCS, FWCS, SBCS and RPCS) are assumed to be not operating.

4. Code Simulation Results

Figure 1 shows the comparison of RCS pressure transients for the overpressure protection (OP) analysis. As expected, the RCS peak pressure of 2693.4 psia is the exactly same in both cases. The results for POSRV closing time of 0.95 seconds and 1.50 seconds are compared in this figure.

The comparison of the SIAS reaching time predicted by the KISPAC code during the loss of load event is shown in Table 2.

Table 2. Comparison of SIAS Reaching Time

Total Closing Time of POSRV	SIAS (1810 psia) Occurrence (psia)	PZR Min. Pressure (psia)
1.5 (sec.)	X	1885.2 at 67.3 sec
3.0 (sec.)	X	1837.8 at 67.0 sec
3.5 (sec.)	X	1822.7 at 66.9 sec
3.8 (sec.)	X	1813.7 at 66.8 sec
3.9 (sec.)	X	1810.8 at 66.8 sec
4.0 (sec.)	1809.99 at 62.8 sec	1807.8 at 66.6 sec
5.0 (sec.)	1809.99 at 47.3 sec	1778.9 at 66.4 sec

In Table 2, SIAS occurs at 4.0 seconds of the total closing time of POSRV. It means that the closing time of POSRV longer than 4.0 seconds may initiate SIAS. Thus, an unnecessary ECCS actuation would happen in a loss of load event. And, the safety injection could induce an over-cooling event in the plant.

Figure 2 shows the comparison of PZR pressure behaviors for 3 cases of events with 1.5, 3.0 and 4.0 seconds of the POSRV closing time. As the POSRV closing time increased, the PZR pressure decreased and resulted in a more steam discharge through POSRV. In case of 4.0 seconds of the closing time, PZR pressure reaches SIAS setpoint (1810 psia) at 62.8 seconds.

POSRV discharge flow rates are compared in Figure 3. As expected, the more POSRV closing time increases, the more steam discharge through POSRV increases. The duration of the steam discharge through POSRV for T1.5, T3.0 and T4.0 are 5.45 seconds, 6.95 seconds and 7.95 seconds, respectively.

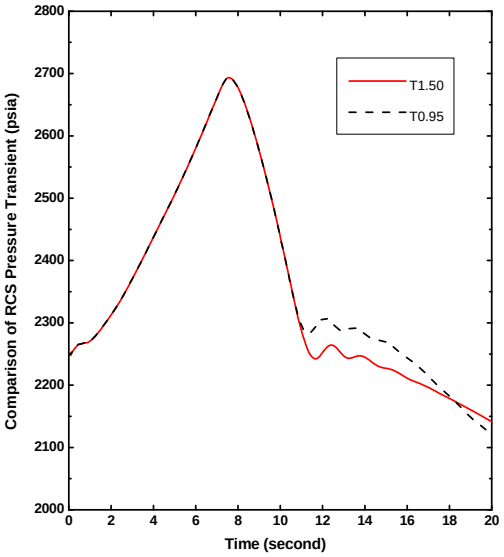

Figure 1. Comparison of RCS Pressures for OP Analysis

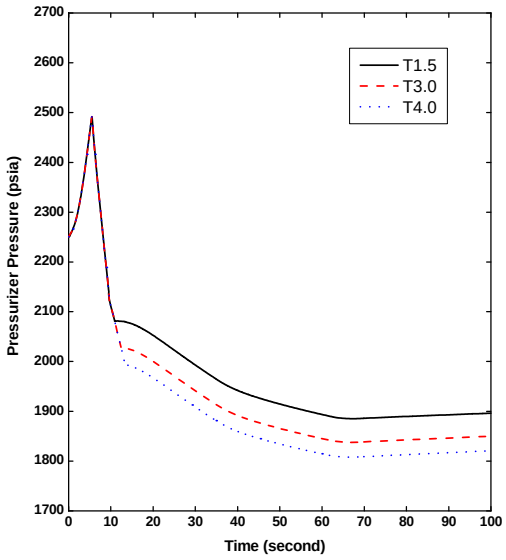

Figure 2. Comparison of PZR Pressures

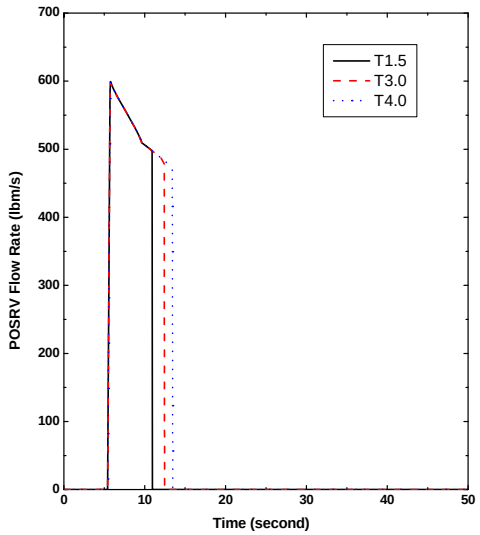

Figure 3. Comparison of POSRV Discharge Flow Rate

As explained in Table 2, KISPAC analysis results show that the proposed closing time (1.5 seconds) is acceptable in APR1400.

5. Conclusions

To evaluate the effect of the change of POSRV closing time for the APR1400 plant, the analyses have been performed by the code simulation from the viewpoint of the overpressure protection and SIAS actuation.

The increase of the POSRV closing time has no effect on the peak pressure results of the overpressure protection analysis.

Also, the evaluation results have shown that the maximum acceptable time of the POSRV closing time preventing Safety Injection is about 4 seconds.

Therefore, it is concluded that the proposed POSRV closing time (1.5 seconds) is acceptable for the design operational transients in APR1400.

REFERENCES

[1] “Overpressure Protection”, ASME Boiler and Pressure Vessel Code Section III, Article NB-7000

[2] U.S. NRC, Standard Review Plan Section 5.5.2, Over-pressure Protection, Rev.2, NUREG-0800, November 2007.