OPR1000 Overpressure Protection Analysis with an Increased MSSV Opening Uncertainty

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1. Introduction

The overpressure protection for OPR1000 Reactor Coolant System (RCS) and the Steam Generators (SG) is provided by means of Pressurizer Safety Valves (PSV), Main Steam Safety Valves (MSSV) and Plant Protection System (PPS).

MSSVs are periodically tested in accordance with the ASME OM Code inservice test requirements to verify that their opening uncertainties are maintained within the limits specified in technical specification. And MSSV inservice tests carried out in OPR1000 showed the valve opening uncertainty may have greater value than expected due to the uncertainties originating from the setpoint measurement accuracy and setpoint drift.

To evaluate the effect of the increased MSSV opening uncertainty on the plant overpressure protection, an analysis has been performed in a manner that verifies the validity of the OPR1000 overpressure protection which was determined at the stage of plant licensing.

2. Analysis Methods

The loss of load event in conjunction with a delayed reactor trip is chosen as the design basis for the sizing of the primary safety valves. This event is the most severe one among the abnormal operational transients required by NUREG-0800 [1, 2].

The analysis of this transient is performed with the KISPAC computer code [3], which has been verified extensively by comparing with operating plant data. The code includes models for the reactor vessel, core, hot legs, cold legs, steam generators, pressurizer (PZR) and reactor coolant pumps. Other modeled systems include the feedtrain, steam lines, auxiliary feedwater, plant protection, and plant control systems.

Many conservative assumptions are used to make the event the severest one in this analysis. Thses assumptions are summarized as follows:

(1) The highest possible power
(Maximum reated output plus 2%)
(2) The least negative MTC and FTC
(3) No credit for CVCS letdown flow, pressurizer (PZR) spray flow, steam bypass system actuation, RPCS actuation, and feedwater addition
(4) Plant instrumentation response time delay and safety valve setpoint tolerances
(5) Reactor scram initiation by the second safety-grade signal from the PPS.
(6) 5% of MSSV opening uncertainty

A parametric study is performed to find out the initial conditions that maximize the RCS/SG pressurization and the PZR water level swell.

3. Simulations and Results

The loss of load event was analyzed with various initial PZR pressures and water levels to determine the initial values that maximize the RCS/SG pressurization and the PZR water level swell.

The maximum RCS peak pressure could be obtained with an initial PZR pressure that results in a coincident energy relief by the PSV and MSSV.

A lower PZR water level resulted in a slower RCS pressurization compared to the cases with a higher initial PZR water level.

Based on the parametric study, the case with the initial PZR pressure of 2250 psia and PZR water level of 21.9% experienced the maximum RCS pressurization during the transient.

As for SG pressurization, the case with the lowest initial PZR level and pressure resulted in higher steam generator peak pressure because a lower primary energy slows SG pressurization and MSSV opening.

For PZR level swell point of view, the case with the highest initial PZR level and pressure yielded the largest water level swell.

Table 1 shows the comparison of the analysis results with the ones performed for initial plant licensing. Due to the MSSV uncertainty increase, the SG peak pressure was about 50 psia higher, while the RCS peak pressure was almost the same as compared with the previous analysis results.

Figures 1 through 3 show the analysis results of the loss of load event with a delayed reactor trip.

4. Conclusion

During the loss of load event in conjunction with a delayed reactor trip, the RCS and SG are being pressurized. Because the opening uncertainty of the MSSV is assumed 5% of opening setpoint, the RCS and SG peak pressure, especially SG, have higher values than those of the previous analysis, which was 1% of MSSV opening uncertainty. However, as shown in the analysis results, the RCS and SG pressure is still below the 110% of their design pressure, meeting the overpressure protection requirements. Although PZR level swell was calculated conservatively, the PSVs do not have the potential for passing any liquid during the event.

Therefore, it is concluded that OPR1000 has the overpressure protection capability, even considering the increase in the MSSV opening uncertainty.

ACKNOWLEDGEMENT

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REFERENCES

1. U.S. NRC, Standard Review Plan Section 5.2.2, Overpressure Protection, Draft Rev. 3, April 1996.
2. “Overpressure Protection”, ASME Boiler and Pressure Vessel Code Section III, Article NB-7000.
3. KOPEC, KISPAC CODE Manual, September 30, 2004.

Table 1. Comparison of analysis results

Parameters	Unit	MSSV 1% uncertainty	MSSV 5% uncertainty
Pressurizer Peak Pressure	psia	2547.5	2541.2
RCS Peak Pressure	psia	2664.0	2667.1
SG Peak Pressure	psia	1334	1382.8
Reactor Trip Signal Generation Time	sec.	4.9	5.41
Max. PZR Integral Insurge Mass	lbm	8853.3	8804.4
PSV Opening Time	sec.	6.2	7.37
Reactor Trip Occurrence Time	sec.	6.15	6.56
Maximum PZR Level	%	90.35	93.4

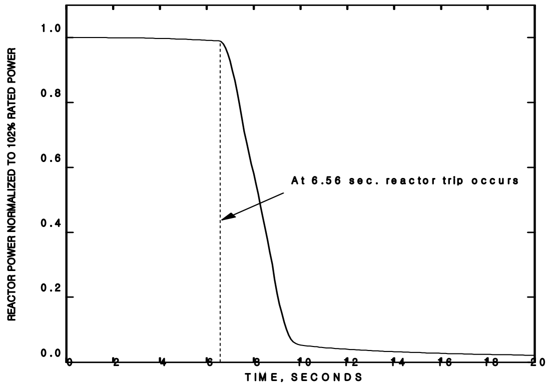

Figure 1. Maximum Reactor Power Normalized to 102% Rated Power vs Time for the Worst Case, Loss of Load Incident

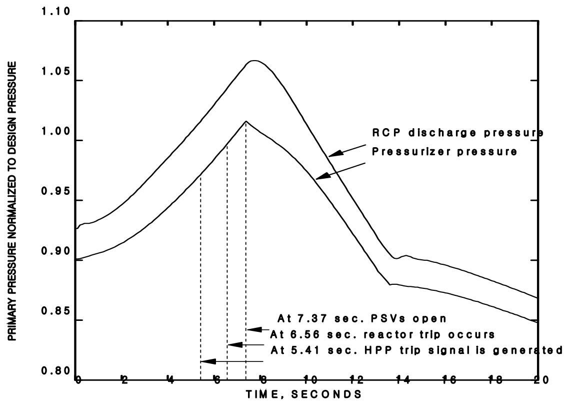

Figure 2. Maximum Reactor Coolant System Pressure Normalized to Design Pressure vs. Time for the Worst Case, Loss of Load Incident

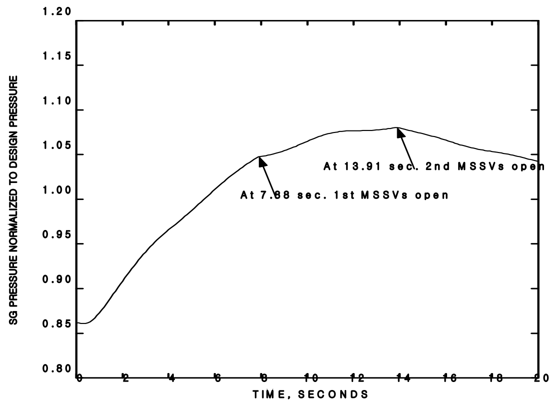

Figure 3. SG Pressure Normalized to Design Pressure vs. Time for the Worst Case, Loss of Load Incident