# Overpressure Protection Analysis for the SMART-P

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## 1. Introduction

Generally, in commercial pressurized water reactors (PWRs), the overpressure protection for the reactor coolant system and steam generators is in accordance with the requirements set forth in the ASME Boiler and Pressure Vessel Code, Section III [1], and is accomplished by means of pressurizer safety valves (PSVs), main steam safety valves (MSSVs), and a reactor protection system (RPS). In the SMART-P design, the MSSVs are removed and the Pilot Operated Safety Relief Valves (POSRVs) and the RPS provide the overpressure protection capability.

In this study, the overpressure protection analysis for the SMART-P has been performed with a methodology currently used for the commercial reactor and the TASS/SMR (Transients And Setpoint Simulation/Small and Medium Reactor) code.

## 2. The Characteristics of the POSRV

For the overpressure protection of the SMART-P, 3 CCI POSRVs are installed at the top of the 3 gas cylinders [2]. Contrary to the PSV, the characteristic of the POSRV is the opening/closing dead time. The dead time is the time interval between the time at which the pressurizer pressure reaches an opening or closing setpoint and the time at which the POSRV starts to open or close. The dead times for opening and closing considered in this analysis are 0.2 and 0.6 seconds, respectively. After this dead time, the valve opens or closes linearly from the full closed to the full open state or vice versa in 0.3 or 0.5 seconds, respectively.

## 3. Analysis Method

The overpressure protection analysis for the SMART-P is accomplished by the TASS/SMR code [3]. In addition, the following assumptions are considered to conservatively evaluate the system's pressurization during the events.

- The reactor trip is initiated by the second safety grade signal from the RPS.
- Between zero and the most negative moderator temperature coefficient (MTC) provided for the safety analysis, the MTC is selected, from a viewpoint of the system pressurization. Similar to the MTC, a fuel temperature coefficient (FTC) is also selected between the least and the most negative FTC provided for the safety analysis.
- The POSRVs are assumed to open at 17.17 MPa by considering their opening setpoint (17.0 MPa) with a 1% uncertainty. The closing setpoint is determined by considering a 12% blow down rate.
- All three pressurizer safety valves (CCI POSRVs) will be credited. On the other hand, 3 out of 4 trains of the PRHRS are operable after the occurrence of the second safety grade reactor trip signal.

There are several kinds of reactor trip functions in the SMART-P. Their setpoints and signal delay times considered in this analysis are shown in Table. 1.

Table 1. Trip Signals Setpoints and Signal Delay Times

| Trip Signals | Setpoint | Signal Delay Time |
|---|---|---|
| Low CHFR | 1.4* | 0.1 sec |
| High Core Power | 122.2% | 0.425 sec |
| High PZR Pressure | 16.44 MPa | 0.975 sec |
| High SG Pressure | 4.74 MPa | 1.125 sec |
| Low MCP Speed | 77.25% | - |
| Low FW flow | 10% | 1.2 sec |

**: CHFR trip setpoint is arbitrary value just for the conservative evaluation in this paper. The appropriate setpoint will be carefully determined later.*

## 4. Results and Discussion

Section III.5 of the standard review plan 5.2.2 describes that all transients analyzed in chapter 15 of the safety analysis report that result in an increase in the pressure experienced by the reactor coolant pressure boundary are examined [4]. Therefore, the transients, categorized into a decrease in the heat removal by the secondary system and the reactivity and power distribution anomalies, can be considered as an initiating event for the overpressure protection.

### *4.1 Decrease in the Heat Removal by the Secondary System*

The volume of the SMART-P steam generator (SG) secondary side is relatively small compared to the commercial PWRs. Therefore, the pressure of the SG secondary side sharply increases if the main turbine stop valve closes. In addition, the feed water (FW) flow gradually decreases as the SG pressure increases. In the SMART-P design, the high SG pressure and low FW flow signals are adopted in the trip functions. Therefore, after the initiating events (i.e. the loss of external load, turbine stop and the loss of condenser vacuum), which close the turbine stop valve, the first and the second trips occur within a few seconds. In the case of a loss of the non-emergency AC power, the main coolant pumps and FW pumps simultaneously trip with the initiating event. Therefore, the first trip (MCP low speed) and the second trip (low FW flow) also occur within a few seconds. In these initiating events, the rapid occurrence of the first and second trip signals, the system pressurization is not of concern. On the other hand, in the loss of feed-water (LOFW), the second trip signal by the high pressurizer pressure occurs with a time delay and the pressurization of the system is expected to be much higher. Thus the LOFW event is considered as the initiating event.

Figure 1 shows the core power and system pressure behaviors in the case of the LOFW. For a conservative analysis, the FW flow is set to be zero at 0.0 second and the most negative FTC is used. On the other hand, the MTC is not used in this analysis. The first and second trip signals occur at 0.0 and 7.3 sec, by a low FW flow and a high pressurizer pressure, respectively. The initial condition of a 103% core power, 315°C core exit coolant temperature, 13.9MPa system pressure, 322.5 kg/sec core inlet mass flow rate and –0.6 axial offset pressurize the system more than the other initial conditions. The system pressure increases and reaches the opening setpoint of the POSRVs at ~10.8 second. After the opening of the POSRVs, the system pressure rapidly decreases and stabilizes by the actuation of the PRHRS. The peak pressure of the system is calculated to be 17.3 MPa, which is well below the acceptance criteria, 110% of the design pressure (18.7 MPa).

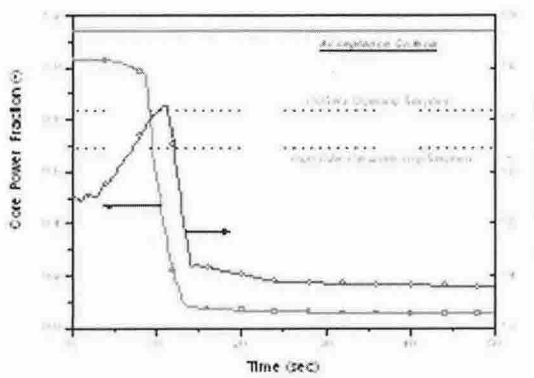

Fig. 1 Core Power & System Pressure Behaviors with Time

*4.2 Reactivity and Power Distribution Anomalies*

The reactivity and power distribution anomalies initiated by the control rod (CR) banks withdrawal event and a single CR bank withdrawal event cause an increase of the system pressure due to the mismatch between the core power generation and heat removal by the secondary system. Specially, in the case of the CR banks withdrawal event, the reactivity worth is comparatively larger than that of the single CR bank withdrawal event and higher system pressurization is expected to occur.Therefore, the initiating event considered in this part is the CR banks withdrawal event.

In the CR banks withdrawal event, the maximum bank worth including the uncertainty (16179 pcm [5]) can be inserted into the core, within different time intervals (57~5000sec). The most negative FTC and MTC are considered for the conservative evaluation. According to the analysis results, the reactor trip is established by different trip functions, depending on the CR banks withdrawal time: the high core power & low CHFR trip signals for quick withdrawal times (50-600 second), the high core power & high pressurizer pressure trip signals for medium withdrawal times (800 & 1000 second) and the high pressurizer pressure & low CHFR signals for long withdrawal times (3000 & 5000 second). The system is not significantly pressurized in the case of the quick and medium withdrawal times (below 1000second) due to the fast occurrence of the second reactor trip signal. On the other hand, as the CR banks withdrawal times are lengthened, the reactor trip by the second signal is considerably delayed. This induces a greater pressurization of the reactor coolant system, as shown in Fig. 2. However, the peak pressure in all the cases of the CR banks withdrawal event is not higher than that in case of the LOFW.

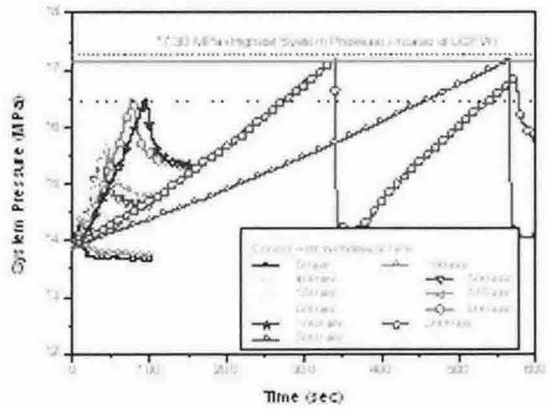

Fig.2 System Pressure Behavior with Time

## 5. Conclusion

With the TASS/SMR code and a methodology currently used for the commercial reactor, an overpressure protection analysis for the SMAT-P with 3 POSRVs has been performed. The peak primary pressure occurs in the case of the LOFW: however, there is a sufficient enough margin when compared to the acceptance criteria, 110% of the design pressure.

## REFERENCES


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