Transient Analysis on the SMART-P Anticipated Transients Without Scram

S.H. YANG[a], K.H. BAE[a], H.C. KIM[a], S.Q. ZEE[a]
[a] *Korea Atomic Energy Research Institute, 150, Dukjin-dong, Yusong-gu, Daejon, 305-353, yangsh@kaeri.re.kr*

1. Introduction

Anticipated transients without scram (ATWS) are anticipated operational occurrences accompanied by a failure of an automatic reactor trip when required. Although the occurrence probability of the ATWS events is considerably low, these events can result in unacceptable consequences, i.e. the pressurization of the reactor coolant system (RCS) up to an unacceptable range and a core-melting situation [1]. Therefore, the regulatory body requests the installation of a protection system against the ATWS events. According to the request, a diverse protection system (DPS) is installed in the SMART-P (System-integrated Modular Advanced ReacTor-Pilot).

This paper presents the results of the transient analysis performed to identify the performance of the SMART-P against the ATWS. In the analysis, the TASS/SMR (Transients And Setpoint Simulation/Small and Medium Reactor) code is applied to identify the thermal hydraulic response of the RCS during the transients.

2. Analysis Method

2.1 Initiating Events

The typical transients for the ATWS are the loss of feed water (LOFW), loss of load, turbine trip, loss of condenser vacuum (LOCV), loss of offsite power (LOOP) and inadvertent control rod withdrawal events [1]. Among these events, the complete loss of main feed water, without turbine trip, is selected as an initiating event for the ATWS analysis of the commercial pressurized water reactors (PWRs) since it produces the highest peak primary pressure [2, 3]. However, the design concepts of the SMART-P are considerably different from those of a commercial PWR. Thus, it is necessary to perform a transient analysis by considering the SMART-P specific ATWS. In this work, decrease in heat transfer by the secondary system and LOOP events are considered as the initiating events for the ATWS.

2.2 Major Assumptions

The nominal initial condition and design data are used in the transient analysis. Major assumptions considered in the analysis are as follows:

- Reactor trip by the plant protection system (PPS) and diverse protection system (DPS) is not considered. The DPS provides a diverse backup to the PPS to reduce the risk of the ATWS. The DPS is a two-channel non-safety grade system featuring two-out-of-two actuation logic. The DPS circuitry is diverse and independent from the existing safety grade RPS. The DPS installed at the SMART-P initiates a reactor trip on a high pressurizer pressure and a high core power.
- Passive residual heat removal system (PRHRS) is actuated by the signals such as a low feed water flow, a high secondary steam generator pressure, LOOP, etc.
- Pilot operated safety relief valve (POSRV), installed at the top of the gas cylinder, is actuated as designed.
- Best-estimate fuel and moderator temperature coefficients are used according to the burn-up condition of the fuel.

2.3 Acceptance Criterion

Acceptance criterion for the ATWS is the ASME Service Level C criteria of 22.06 MPa (3200 psia) [3, 4].

3. Analysis Results

3.1 Decrease in Heat Transfer by the Secondary System

A LOFW, loss of load and LOCV are considered as initiating events for the ATWS analysis in this category. In the absence of a reactor trip, these events result in a primary temperature, a pressurizer level increase and a subsequent pressurizer pressure increase. In the case of a loss of load and LOCV events, the secondary pressure also increases due to the closure of the turbine stop valve. Although the PPS signals, such as a low feed water flow, high pressurizer pressure and high secondary steam generator pressure, etc., are generated, the reactor trip is not accomplished. On the other hand, the PRHRS is actuated normally by a low feed water flow in case of the LOFW event (at 4.5 sec) and by a high secondary steam generator pressure (at ~1.0 sec) in cases of the loss of load and LOCV events. In these three initiating events, the overall behaviors of the core power and primary pressure are similar, as shown in Figs. 1 & 2: initial decrease of the core power due to the moderator temperature feedback, initial increase and gradual decrease of the primary pressure before or after the peak primary pressure according to the heat balance between the heat generation in the core and the heat removal through steam generator. In these three cases, the peak primary pressures are well below the criterion of 22.06 MPa. Moreover, the opening of the POSRVs does not occur. In this category, the LOCV event shows the highest peak primary pressure.

Transient analysis has also been performed at the lower core power levels of 20%, 36% and 50%. At the 20% and 50% core power levels, the main coolant pump (MCP) is in a low-speed and high-speed condition, respectively. On the other hand, at the 36% core power level, low-speed and high-speed conditions are possible. Fig. 3 shows the pressure behaviors for the various core powers and MCP speed conditions. Under the same MCP speed condition, a lower power leads to a lower primary pressure.

3.2 Loss of Offsite Power

As a LOOP occurs, MCPs and feed water pumps coast-down and the PRHRS actuates automatically. Decrease in the core mass flow rate causes a rapid increase in the coolant temperature and inserts a larger negative moderator feedback compared to the decrease in the heat removal by the secondary system. Therefore, the decreasing rate of the core power is more rapid than that in the LOCV event. This rapid decrease in the core power less pressurizes the primary system. From the viewpoint of the system pressurization, the LOOP is not the worst initiating event in the SMART-P.

5. Conclusion

Using the TASS/SMR code, a transient analysis has been performed to identify the performance of the SMART-P against the ATWS. In this analysis, decrease in heat transfer by the secondary system and LOOP are considered as the initiating events of the ATWS. According to the analysis, the peak RCS pressure can be found in the case of the LOCV event: however, the peak pressure is well below the acceptance criteria of 22.06 MPa. In addition, a transient analysis at different core power levels has also been performed. The peak pressure decreases as the initial core power decreases.

REFERENCES

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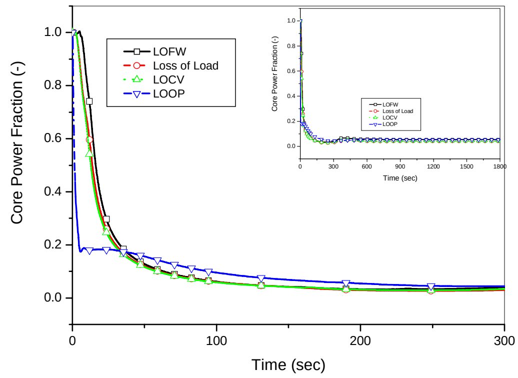

Fig. 1 Core Power Behavior

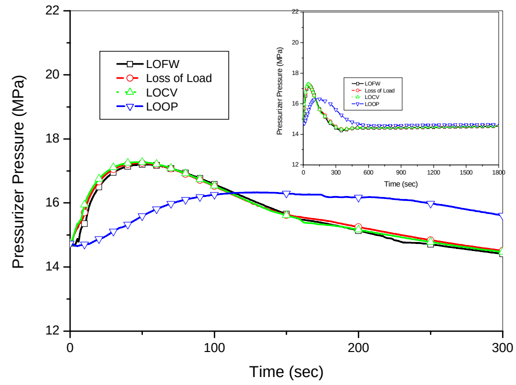

Fig. 2 Primary Pressure Behavior

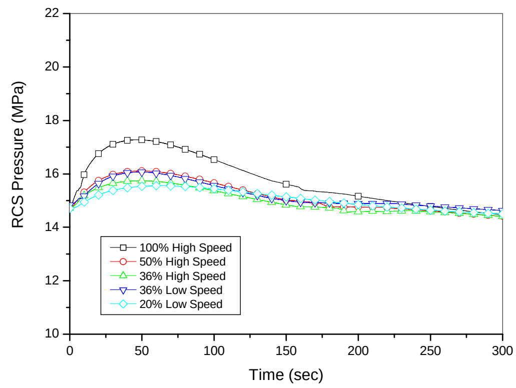

Fig. 3 RCS Pressure Behavior