Preliminary Evaluation of the Diverse Protection System in PGSFR

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1. Introduction

The anticipated transient without scram (ATWS) is defined as an abnormal transient with failure of scram actuation. It is one of the "worst case" accident based on the United States Nuclear Regulatory Commission (U.S.NRC). Consideration frequently motivates the NRC to take regulatory action. An evaluation of this event is also a general requirement due to a potential safety issue that may lead to core damage under postulated condition.

This paper estimated the set-points sensitivity test of the diverse protection system (DPS) related with unprotected events of the prototype generation-IV sodium cooled fast reactor (PGSFR) including unprotected transient over power (UTOP) and unprotected loss of flow (ULOF) by MARS-LMR code. The variation of the power to flow (P/Q) of UTOP and ULOF is illustrated to conduct the set-points sensitivity test of DPS. Also we estimated the effect of the DPS introduction after selecting UTOP, ULOF event as the unprotected events which are predicted to aggravate the events.

2. PGSFR characteristics and Analysis methodology

Analysis methodology depends on classification of events. For example, conservative analysis methodology is applied to DBEs. However, the best estimation approach is applied to a design extended condition (DEC) with sensitivity tests. Fig. 1 shows safety analysis code system of PGSFR, which indicates that MARS-LMR code will be used as the safety analysis code for DEC events. The MARS-LMR is a version of modified MARS code for a sodium cooled fast reactor. Thermal-hydraulic correlations for SFR including heat exchanger, bundle, and wire-wrapped fuel rod bundle were supplemented in the MARS-LMR [1]. The MARS-LMR code can simulate a multiple heat transport system modules and its associated controllers. Fig. 2 shows a plant schematic of the PGSFR with major components. A primary heat transport system (PHTS) is represented with the reactor vessel flow passages, the primary

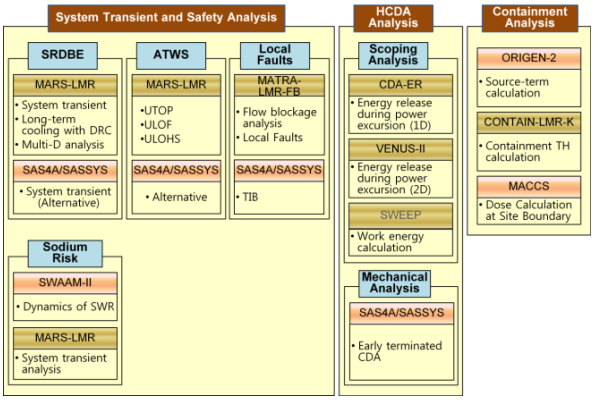

Figure 1 Safety Analysis Code System

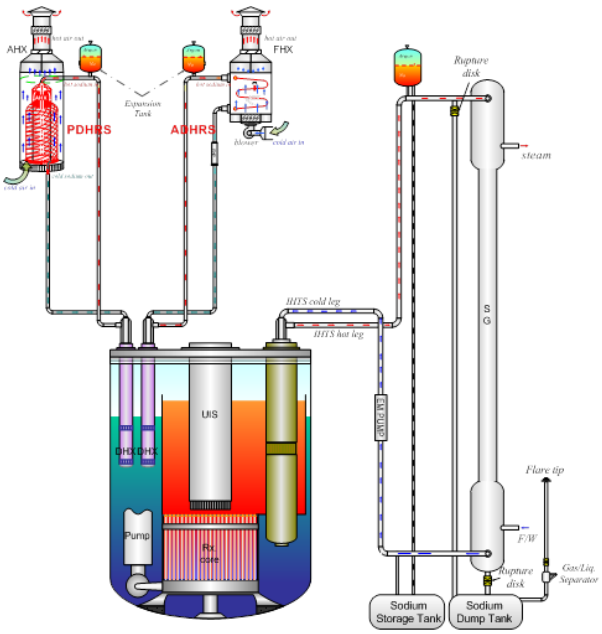

Figure 2 Schematic of the PGSFR

pump, and the shell side of the IHX. An intermediate heat transport system (IHTS) is represented with the tube side of the IHX, piping, the shell side of the SG, and the intermediate pump [2].

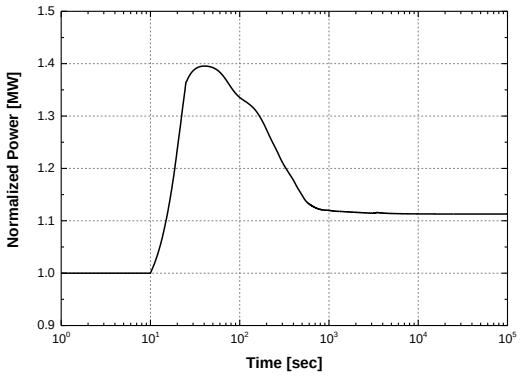

Figure 3 Reactor power during the UTOP event for nominal fuel conditions

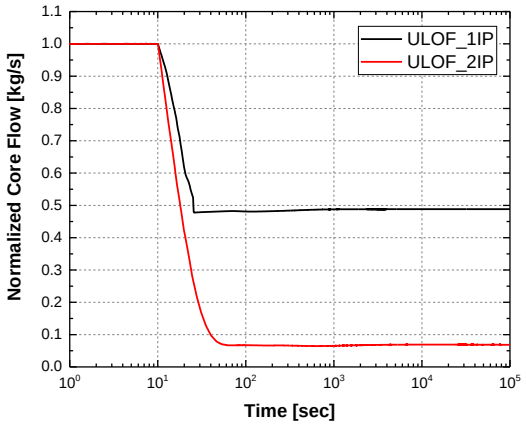

Figure 4 Normalized core flows of nominal fuel conditions for the ULOF events

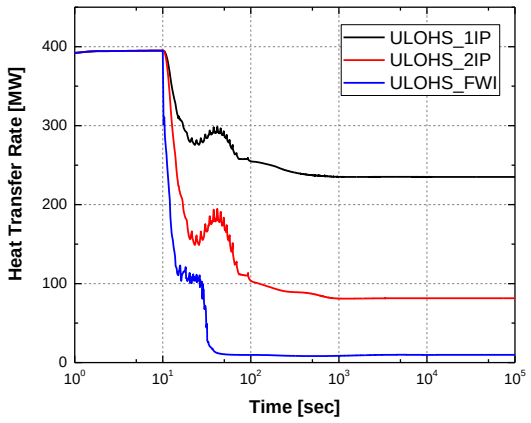

Figure 5 Heat transfer rate in the steam generators for nominal fuel conditions during the ULOHS events

3. ATWS events of PGSFR

Preliminary to evaluate DPS capability of PGSFR, some ATWSs were selected as follows:

3.1 UTOP

First, UTOP was selected as ATWS event which requires a DPS system. The UTOP event initiated at the full power by a possible malfunction of the reactivity controller which causes the shim motor to withdraw a single control rod until the driveline reach the rod stop due to either the reactor protection system (RPS) failure to detect the transient or the control rod failure to unlatch. During the UTOP, the power peak was about 1.4 times of the rated full power condition. And final equilibrium power is 1.1 times higher than the full power condition as shown in Fig. 3[2].

3.2 ULOF

Two loss of flow event for ATWS events are selected as follows:

♦ Unprotected spurious one PHTS pump trip (ULOF-1PP)
♦ Unprotected loss of power to all PHTS pumps (ULOF-2PP)

The ULOF-1PP event is initiated with one primary pump failure, so the core flow is gradually reduced with the pump coast-down. In this analysis, the core flows are reduced from about 1989 kg/s about 967 kg/s, which are slightly smaller than 50% of the nominal full power flow condition (Fig. 4).

The ULOF-2PP event is initiated with all primary pump failure, so the core flow is gradually reduced with a pump coast-down. In this analysis, the core flows are reduced from about 1989 kg/s to about 134 kg/s, which are slightly higher than 5% of the normal flow condition (Fig. 4)[3].

3.3 ULOHS

Three loss of heat sink event are selected as follows:

♦ Unprotected spurious one IHTS pump trip (ULOHS-1IP)
♦ Unprotected loss of power to all IHTS pump (ULOHS-2IP)
♦ Unprotected loss of normal FW due to pump failure (ULOHS-FWI)

The ULOHS-1IP and the ULOHS-2IP are initiated by one and all intermediate pump trip, respectively. There is no coast-down when the intermediate pump is stopped, due to characteristics of an EM-pump. Therefore, the heat removal rate through the SG connected failed pump is reduced to 235.07 MW and 81.48 MW, respectively as shown in Fig. 5.

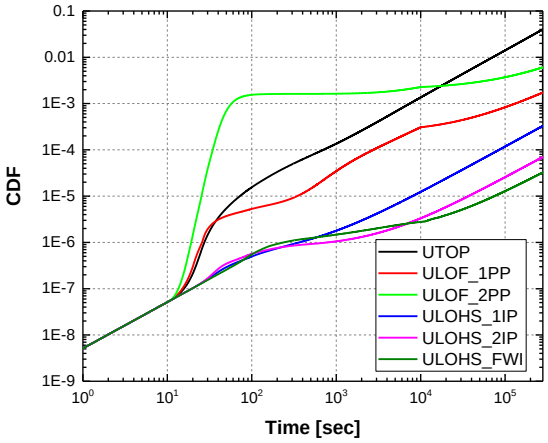

Figure 6 CDF during the DECs events

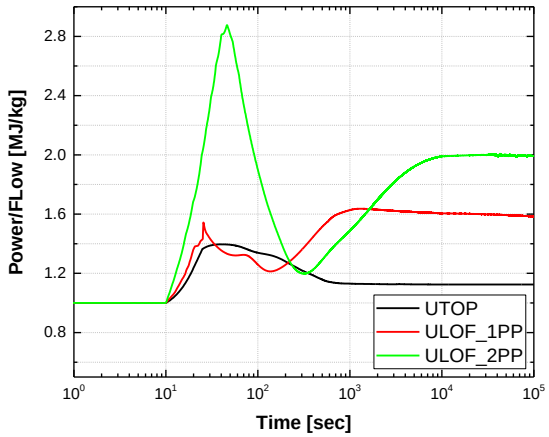

Figure 7 Power/Flow during the DECs events

The ULOHS-FWI is initiated by feed-water system isolation, which is defined that all feed-water supply is stopped with responsible for all feed-water pumps failure. Therefore, the convection heat removal through the steam generator is not available (Fig. 5)[4].

4. DPS

The major protection system in the PGSFR is the safety-grade RPS. DPS, a non-safety system, provides partial back-up means to the RPS, and it provides diverse methods to trip the reactor, and also to initiate some engineered safety feature (ESF) functions to satisfy the ATWS requirements [5,6].

Fig. 6 shows CDF which is a parameter defined in fuel performance as the safety limits. This paper estimated the effect of the DPS introduction after

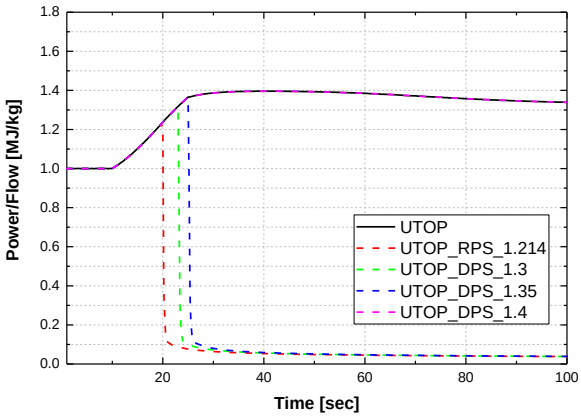

Figure 8 Power/Flow during the UTOP event for different set-points of DPS

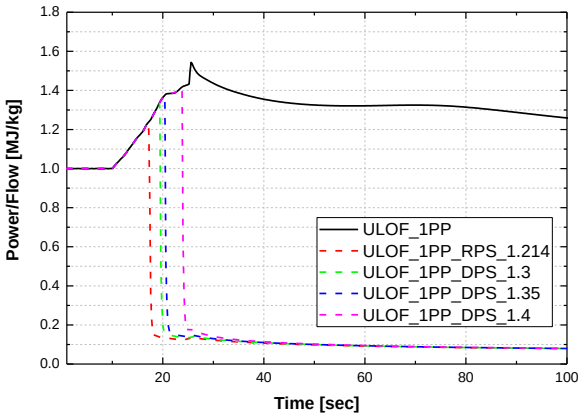

Figure 9 Power/Flow during the ULOF_1PP event for different set-points of DPS

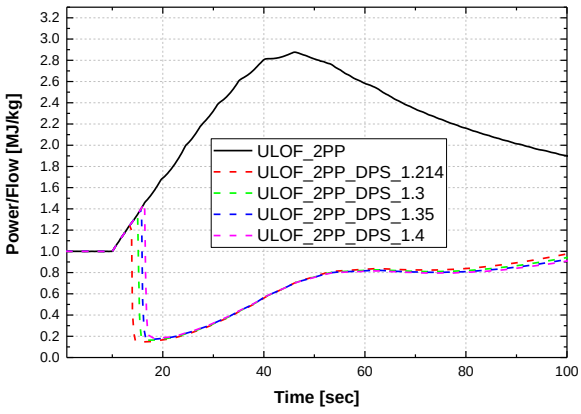

Figure 10 Power/Flow during the ULOF_2PP event for different set-points of DPS

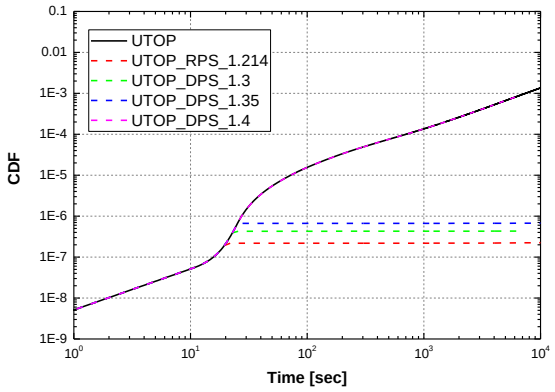

Figure 11 CDF during the UTOP event for different set-points of DPS

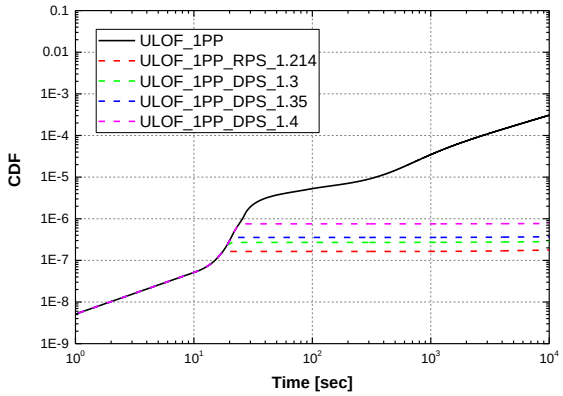

Figure 12 CDF during the ULOF_1PP event for different set-points of DPS

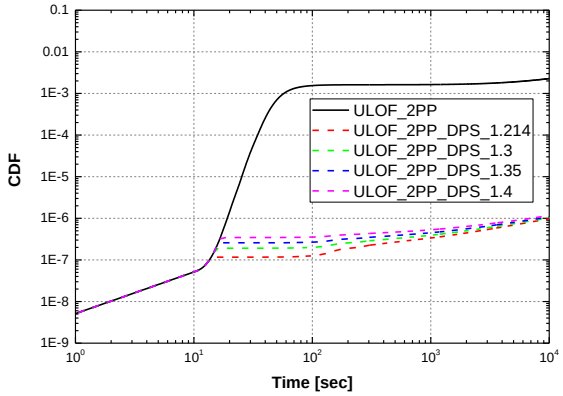

Fig. 13 CDF during the ULOF_2PP event for different set-points of DPS

selecting UTOP, ULOF event as unprotected events which are predicted to aggravate the events.

DPS uses power to flow (P/Q) as a trip signal. In the RPS case, the reactor trip occurs at P/Q=1.214. This paper illustrates the variation of P/Q of UTOP and ULOF for conducting the set-points sensitivity test of DPS in Fig 7. It is assumed that the set-points are P/Q=1.3, 1.35 and 1.4 to operate DPS based on UTOP event.

Fig. 8 indicates the variation of P/Q according to the difference set-points of DPS. The reactor trip occurs at 20.0seconds for RPS(P/Q=1.214) and 23.1, 25.1 seconds for DPS(P/Q=1.3, 1.35) respectively after initiating accidents. The reactor trip does not occur at P/Q=1.4 because it doesn't exceed 1.4 in UTOP. As can be seen in Fig. 9-10, different ATWS events were analyzed with the same set-points. However, the reactor trip occurs at even P/Q=1.4 which is different from UTOP.

Fig. 11 indicates CDF values according to the various set-points of DPS. It can be found that CDF values are stable as soon as introducing RPS and DPS, also the occurring time of reactor trip is the same with those of Fig. 8. For P/Q=1.35, CDF values after 10^4 seconds reduced to 1% of CDF values before applying DPS. Fig. 12-13 show the similar tendency, also there is no significant difference between RPS and DPS about the initiating time of each event.

5. Conclusion

This paper estimated the set-points sensitivity test of DPS related with unprotected events of PGSFR including UTOP and ULOF by MARS-LMR code. The results indicated that there is no significant difference in both RPS and DPS about the initiating time of each event. Therefore, this study found that the urgent manage for safety of the reactor when RPS failed is possible by the applying DPS.

REFERENCES

[1] HY Jeong, "Thermal-hydraulic model in MARS-LMR code," KAERI/TR-4297/ 2011, 2011.
[2] Chiwoong CHOI, "UTOP Events Analyses of the PGSFR using MARS-LMR," KAERI/TR-5735/2014, Feb. 2015.
[3] Chiwoong CHOI, "ULOF Events Analyses of the PGSFR using MARS-LMR," KAERI/TR-5735/2014, Feb. 2015.
[4] Chiwoong CHOI, "ULOHS Events Analyses of the PGSFR using MARS-LMR," KAERI/TR-5735/2014, Feb. 2015.
[5] 10 CFR 50.62, "Requirements for reduction of risk from ATWS events for light-water-cooled nuclear power plants," August 28, 2007.
[6] U.S. NRC, SECY 93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and ALWR Designs," July 21, 1993.