Assessment of Flow Instability in Passive Auxiliary Feedwater System (PAFS) Using RELAP5

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1. Introduction

In South Korea, as an improved safety design concept, Passive Auxiliary Feedwater System (PAFS) has been developed to be adopted in Advanced Power Reactor Plus (APR+). Since PAFS is two-phase flow system, flow instabilities may occur. Flow instabilities may cause the severe deterioration of heat removal capability of PAFS due to the reduction of the condensate flow. For the reliable operation of PAFS, it is required to assess the flow instabilities in PAFS.

The Ledinegg-type instability and the Density Wave Oscillation (DWO) are the representative static flow instability and the dynamic flow instability, respectively. In this study, the occurrence possibility of both instabilities in PAFS is assessed with the best-estimate thermal hydraulic code, RELAP5.

2. Assessment Method

In order to assess the flow instability, this study used the APR+ PAFS input model. For various operation conditions, in order to generate the steady-state PAFS flow rate, this study simplified the APR+ PAFS input model as shown in Fig. 1. By controlling the heat source in the Steam Generator (SG) and the heat sink in PAFS, the heat balance was accomplished and various PAFS flow rates were obtained.

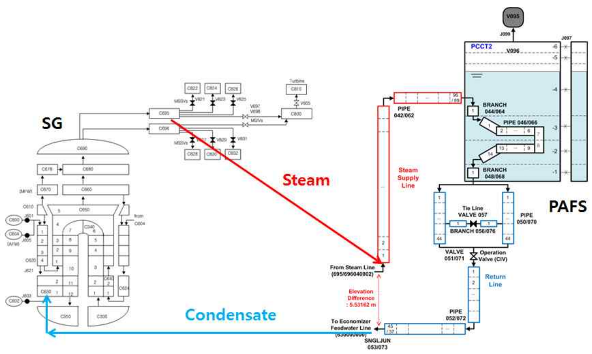

Fig. 1. RELAP5 nodalization for simplified APR+ PAFS

Figures 2 to 5 show the calculation results for the case that PAFS flow rate is 51 kg/s and the operation pressure is 60 bar as a sample case. After 1000 s, the steady state was accomplished well in terms the SG pressure, PAFS flow rate, heat transfer rate and return line water level.

In the same way, the steady-state PAFS flow rates were obtained for various operation conditions as shown in Fig. 6. The PAFS flow rate increases with the PAFS heat removal rate.

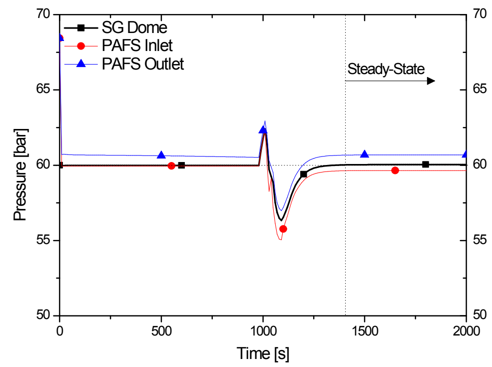

Fig. 2. SG pressure

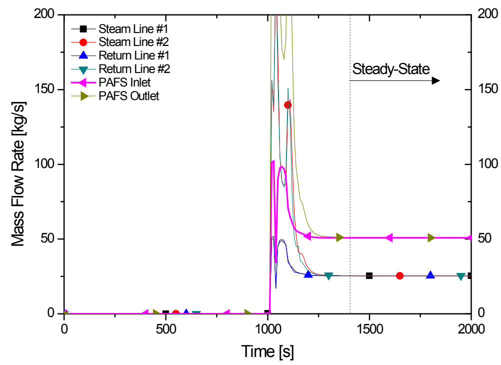

Fig. 3. PAFS flow rate

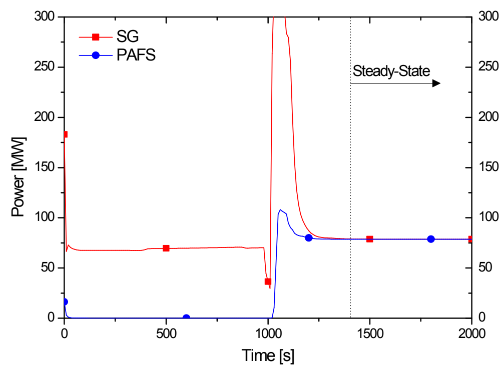

Fig. 4. Heat transfer capacity of SG and PAFS

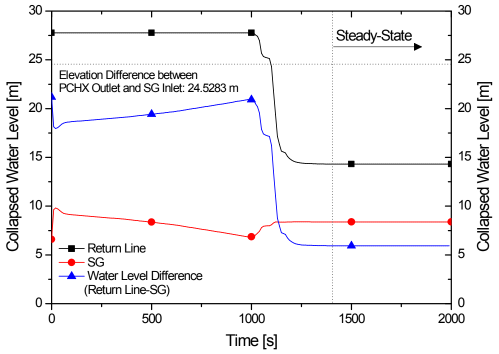

Fig. 5. RELAP5 return line water level

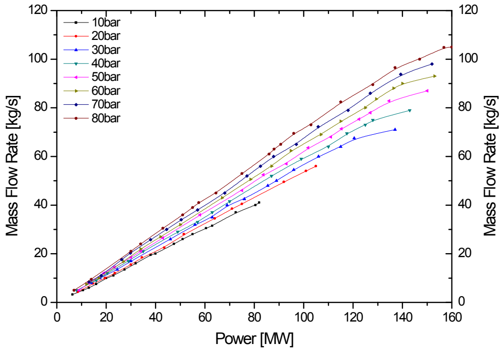

Fig. 6. PAFS flow rate for all SG pressure

3. Possibility of Ledinegg Instability

Figure 7 shows the pressure drop curve for various PAFS operation pressure. The pressure drop increases with PAFS flow rate. The negative slope section does not appear. Therefore, it is concluded that the Ledinegg flow instability does not occur in PAFS.

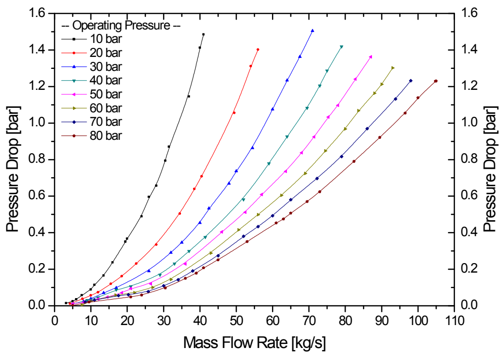

Fig. 7. Pressure drop curve

4. Possibility of Density Wave Oscillation

Figure 8 shows the PAFS flow rate for the case that PAFS flow rate is 7.6 kg/s and the operation pressure is 20 bar as a sample case.

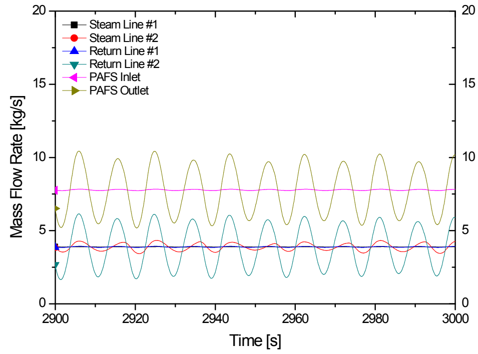

Fig. 8. RELAP5 nodalization

Figure 9 shows the pressure drop curve for various PAFS operation pressure. Conditions that the DWO occurs are marked as red circle. When the PAFS flow rate is less than ~30 kg/s, the DWO might occur in PAFS. However, the amplitudes of the flow rate and the capacity were not large.

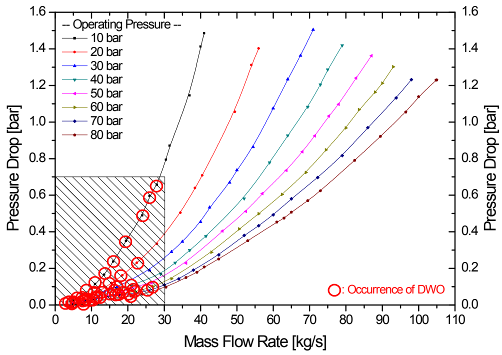

Fig. 9. RELAP5 nodalization

3. Conclusions

From the RELAP5 code analysis, the Ledinegg instability might not occur in PAFS. The DWO might occur in PAFS but the effect of the oscillation on the heat removal capacity of PAFS was not large. Therefore, it is concluded that PAFS is safe in terms of flow instabilities.

ACKNOWLEDGMENTS

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