Preliminary Study of Steam Generator Water Level Tracking by Three Different Methods Using RELAP5/MOD3

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1. Introduction

It has been identified in the previous works that the tracking of a steam generator (SG) water level is important. However, three different parameters can be used as an indicator of the SG water level. These parameters are: (1) SG downcomer collapsed water level, (2) water mass inventory and (3) pressure differential between upper and low tap of SG [1].

Most of system analysis codes do not calculate the SG water level based on the pressure differential between upper and lower tap of SG. Instead the SG water level is calculated by either SG downcomer collapsed water level or water mass inventory.

However, the pressure differential measurement is the most widely used method for estimating the SG water level in the experiment as well as in the industry

In this paper, therefore, three events are analyzed to perform sensitivity study of the SG water level calculation with RELAP5/MOD3 [2] and evaluate SG level difference by three parameters.

2. Method

. The relationship of three parameters to the SG water level simulated by RELAP5/MOD3 can be shown as below:

2.1 SG Downcomer Collapsed Water Level

Level versus SG downcomer collapsed water level

$$SG_{DC} = \sum SG\ downcomer\ volume\ \times voidfracion \quad (1)$$

2.2 Water Mass Inventory

Level versus core power and SG water mass inventory

$$SG_{MASS} = \sum SG\ volume \times total\ density \quad (2)$$

2.3 Pressure Differential between Upper and Lower Tap of the SG

Level versus pressure differential between upper and low tap of SG

$$SG_{PD} = P_{reference} - (P_{lower\ tap} - P_{upper\ tab}) \quad (3)$$

3. Simulation

2.1 Increasing and decreasing feedwater enthalpy scenarios

To check shrinking and swelling effect, the feedwater enthalpy change events are chosen and analyzed. When feedwater enthalpy is decreasing, the cold feedwater enters the bottom of the tube bundle region, which causes the steam bubbles to collapse. This causes a decrease in the volume occupied by the two-phase mixture. Then, the SG water level falls initially (shrinking) instead of rising as should be expected from the mass balance. The opposite phenomenon of swelling occurs when feedwater enthalpy is increasing. As shown in Figures 1 and 2, mass inventory method matches well with the real behavior [3]. However, donwcomer (DC) collapsed level and pressure differential methods show more shrinking and swelling than the mass inventory methods.

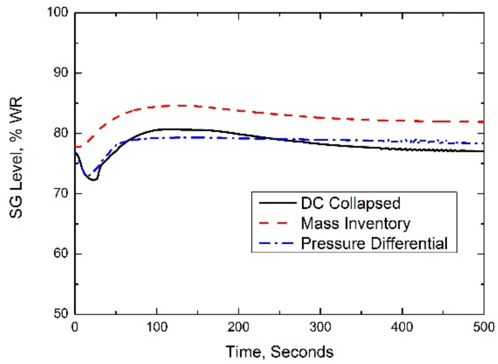

Fig. 1. Decreasing feedwater enthalpy

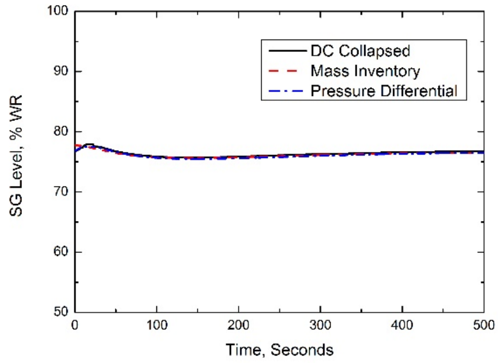

Fig. 2. Increasing feedwater enthalpy

2.2 Total Loss of Feedwater

The SG water level is very important during a Total Loss of Feedwater (TLOFW) event for evaluating a reactor trip time due to Low Steam Generator Level (LSGL), since the reactor trip time directly influences the steam generator dry-out time and first opening time of Safety Depressurization Vent System (SDVS). As shown in Figure 3, the maximum time difference of the reactor trip is 10 seconds by LSGL and it causes significant time difference for the steam generator dry-out time and first opening time of SDVS.

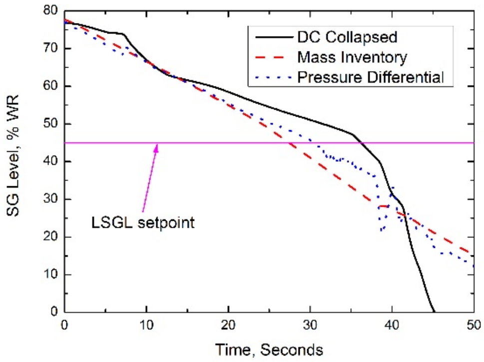

Fig. 3. Total loss of feedwater

2.3 Loss of Main Feedwater

Loss of Main Feedwater (LOMF) is simulated to check back-up feedwater initiation time. It is almost the same time for the back-up feedwater initiation, however, Figure 5 shows level behaviors for three parameter are completely different after back-up feedwater initiation. The authors think that the mass inventory recovery rate is faster than the downcomer level recovery rate.

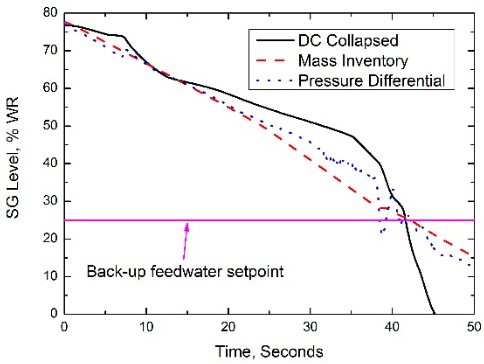

Fig. 4. Loss of main feedwater (short term)

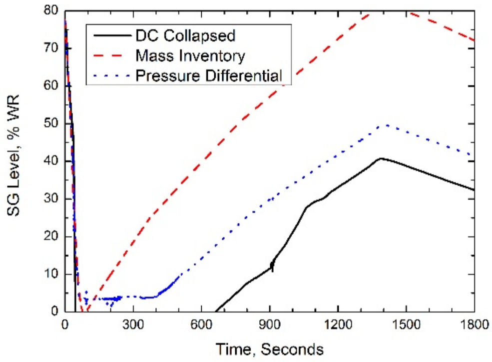

Fig. 5. Loss of main feedwater (long term)

4. Summary and Further Works

In this paper, three events are analyzed using the system analysis code (RELAP5/MOD3) to check for the consistency among the downcomer collapsed water level, mass inventory and the pressure differential measurement methods. This is to identify the sensitivity of the nuclear power plant accident response when one of the above three parameters is selected as the representative parameter of the steam generator water level.

It is confirmed that mass inventory method is not affected by shrinking and swelling effect and the reactor trip time is significantly different among three parameters during TLOFW. In addition, level recovery rate is different when LOMF occurs.

Thus, the SG level sensitivity of SG water level tracking method using three parameters has to be further studied not only for the steady-state operation but also for understanding the nuclear power plant response under various transient scenarios.

REFERENCES

[1] Kimoon Park, “A Quick Review on Steam Generator Water Level Tracking Methods and Its Uncertainties,” May, 2016.

[2] RELAP5/MOD3.3 Code Manual “Volume II: Appendix A. Input Requirements,” January, 2002.

[3] Walter Herbert Strohmayer, “Dynamic Modeling of Vertical U-Tube Steam Generators for Operational Safety Systems,” August, 1982.