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Sensitivity Analysis on Critical Flow Model of RETRAN-3D code on OPR1000 ATWS Event

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1. Introduction

An Anticipated Transient Without Scram (ATWS) event could happen if the reactor protection system that provides a highly reliable means of shutting down the reactor (control rod insertion) fails to work during a reactor anticipated transient event [1]. ATWS event is one of typical Beyond Design Bases Events (BDBE) due to low possibility of occurrence during the lifetime of NPP. Analysis of ATWS is performed based on the best-estimate methodology using transient system analysis codes such as RETRAN-3D code. The major concern in this event is degree of overpressurization in primary reactor coolant system. The major factors that impact on the results of ATWS are behavior of Moderator Temperature Coefficient (MTC), capacity of primary pressure relief using pressurizer safety valve(PSV) and capacity of secondary heat removal using Auxiliary Feedwater(AFW) or Main Steam Safety Valves (MSSV). As a general, the capacity of PSV of OPR1000 is less than that of the Westinghouse-supplied plants in Korea.

Most of thermal-hydraulic transient codes have various critical flow models. The capacity of PSV pressure relief might be affected by selection of critical flow model option. RETAN-3D code includes three(3) critical flow models[4] as follows ; Extended Henry-Fauske, Moody, and Isoenthalpic Expansion/Homogeous Equilibrium.

In this paper, the effect of critical flow models on OPR1000 at ATWS event is investigated using RETRAN-3D code.

2. Analysis method

- **Initial conditions and assumptions**

Initial condition is assumed at full power steady state. Loss of main feedwater event is chosen as a initiating event of ATWS. Main feedwater pump coastdown is not considered in a conservative manner. Auxiliary feedwater system is actuated on steam generator(SG) AFAS (Auxiliary Feedwater Actuation Signal) level with time delay of 45sec. Delay time includes AFAS signal delivery, auxiliary feedwater pump actuation, required time of full flowrate supplied to SG, and so forth. Auxiliary feedwater flow rate range is the minimum of 500 to the maximum of 800 gpm[2]. In this study, flow rate is assumed as 500gpm conservatively. Moderator temperature coefficient (MTC) is assumed -10pcm/°F as 95 % of MTC value during UCN 3 cycle 5. The effects of reactivity parameter due to change of fuel temperature coefficient (FTC) and change of boron concentration are not considered in this analysis.

- **Critical flow model**

As mentioned above, RETRAN-3D code includes three(3) critical flow models. These enable a user to select one among these choking options in calculation of RETRAN-3D. The first option is a combination of the extended Henry-Fauske and Moody models. The second option is a combination of the extended Henry-Fauske and the Isentropic Expansion model. Finally, the Isentropic Expansion model is the third option. The option 2 is recommended by RETRAN-3D utilization.

An area of PSV is adjusted for each choking option based on the design data. During the ATWS event, mass flow via PSV is consisted of steam at the initial stage. Next, mixture of steam and water is released at the second stage. The pure water is released at the final stage. It is predicted that mass flow rate is same as discharging capacity of PSV at the set point at the initial stage. In case of discharging the mixture of steam-water and water, it is predicted that mass flow rate may be exceeded the designed relief capacity. The choice of a choking option affects a behavior of peak pressure, flow rate of mixture of steam-water and water at the discharging stage.

3. Analysis Result

Table 1 represenrs the adjusted area of PSV per each choking option. In the calculation, design data are taken from the document[3] of OPR1000. Valve area for choking option 1 is less than those of the other two options. Valve area for choking option 2 and option 3 are the same.

The less flow rate through PSV area affects the more significant result in ATWS event. In this paper, we use minimum valve area for conservative analysis of ATWS event.

Table 1. Adjusted PSV area with each choking option

Choking option	1	2	3
Min. Area	0.021491	0.022673	0.022673
Max. Area	0.028343	0.029936	0.029936

Figure 1 shows the comparison of PSV flow rate per each choking option. The trend of discharged PSV flow rate shows similar behavior for ATWS event at earlier phase. However, the trend of PSV discharged flow rate changes per each option after 150sec. When the option 1 is selected, PSV closes more rapidly than the other options.

Figure 2 shows the comparison of total discharged mass through PSV per each choking option. Also, total discharged mass for option 1 is less than those of the other two options due to rapid closing of PSV. The total discharged mass through PSV is almost same either option 2 or 3.

Figure 3 shows the trend of pressure at PZR per each choking option. The result shows that the choice of each option has no considerable effect on pressure in PZR.

Figure 4 shows the trend of water volume inside PZR. The discharged flow through PSV consists of mixture of water and steam after 110sec. It can be explained that the pressurizer is filled with RCS coolant swollen due to loss of heat removal at the secondary systems.

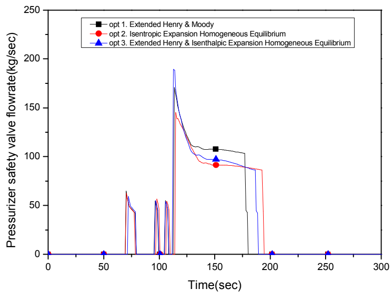

Figure 1. PSV flow rate with choking option

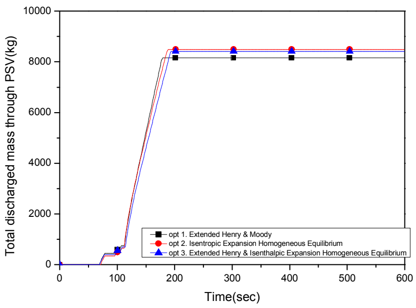

Figure 2. Total discharged mass through PSV

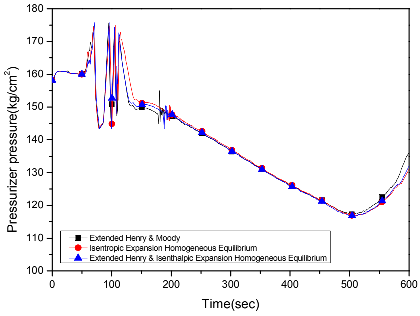

Figure 3. PZR pressure with choking option

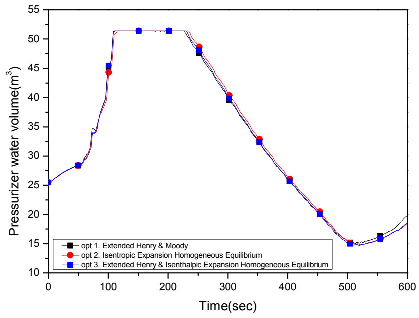

Figure 4. PZR water volume with choking option

4. Conclusion

The sensitivity on critical flow option is examined on behavior of the peak RCS pressure and the discharged mass flow rate during ATWS event using RETRAN-3D code. The results show that the discharged mass flow rate and the predicted RCS peak pressure are not so sensitive in any option.

Therefore, it can be concluded that a combination of the extended Henry-Fauske and the Isentropic Expansion model (option 2), the recommended option of RETRAN-3D is suitable for predicting peak pressure for ATWS event and also, the other two options are not so sensitive to predict the behavior of NPP at ATWS event.

REFERENCES

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