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SGTR Event Analysis of APR1400 on the Effects of Multi-D Modeling Compared with 1D Modeling using MARS Code

Doo-Hyuk Kang, Seung-Wook Lee and Bub-Dong Chung
Korea Atomic Energy Research Institute, 150 Dukjin-dong, Yuseong-gu, Teajon, Korea 305-353
dhkang@kaeri.re.kr, nuclist@kaeri.re.kr and bdchung@kaeri.re.kr

1. Introduction

MARS code has been developed for multi-dimensional best-estimate analysis of commercial LWRs and advanced reactors. Recently, multi-dimensional component has been installed in MARS Code in order to overcome some limitations in application to 3D shear stress dominant phenomena or cylindrical geometry analysis and to allow more flexible 3D models in the system code and to allow the user to model more accurately the multi-dimensional hydrodynamic features of reactor applications, primarily in the vessel and steam generator [1]. In this study, therefore, SGTR (Steam Generator Tube Rupture) event of APR1400 was simulated in order to verify the effects of multi-dimensional modeling compared with one-dimensional modeling.

2. Methods and Results

2.1. MARS modeling for APR1400

APR1400 (Advanced Power Reactor 1400 MWe) is an advanced light water reactor adopting the design features of a direct vessel injection (DVI) configuration and passive fluidic device in the discharge line of the safety injection tank (SIT).

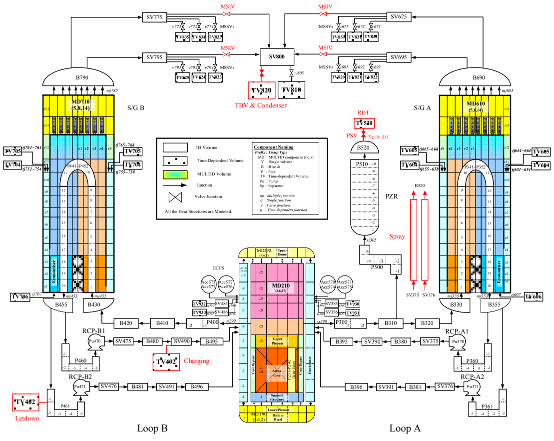


Figure 1. MARS Nodalization for APR1400.

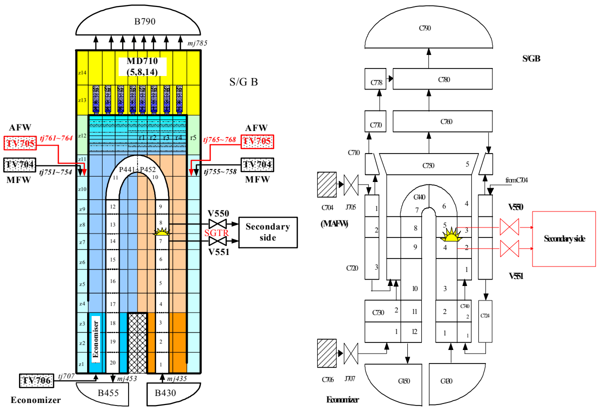
The nodalization diagram of APR1400 for the analysis of the SGTR event is shown in Figure 1. The nuclear steam supply system (NSSS) and several safety systems relevant to the APR1400 such as the core, downcomer, upper head ,bottom head and two steam generators are modeled by the Multi-D component to analyze the full 3D system effect of NPP. The reactor core was modeled with 3×6×27(r-θ-z) nodes and the downcomer has 6 azimuthal sectors with 1 radial ring. The one hot rod was simulated in the core center position. The multiple junctions were used to connect the Multi-D component. The steam generator was modeled with 4×8×14(r-θ-z) nodes. All of the Multi-D components for the APR1400 were summarized at Table 1. The number of total system volume is 2419 and the number of total system heat structure is 2165. This volume number is about 8 times greater than that of the original 1D model. But there are no differences of the system mass and volume compared with the 1D model [2].

Table 1. Geometries of Multi-D component for APR1400.

Name	Type	r	θ	z
Downcomer	Cylindrical	1	6	10
Lower plenum	Cylindrical	4	6	2
Core	Cylindrical	3	6	27
Upper plenum	Cylindrical	4	6	1
Steam generator	Cylindrical	4	8	14

2.2. SGTR modeling description

APR1400 has two steam generators. Steam generator A (S/G A) represents the one installed in loop A where the pressurizer is connected through a surge line while steam generator B (S/G B) represents the one in loop B. For the purpose of simulating a rupture, the two imaginary valves (550, 551) were modeled between the tube side and the shell side of a steam generator.



(a) Multi-D modeling. (b) 1D modeling.

Figure 2. SGTR modeling.

Figure 2 shows how tube rupture was modeled for Multi-D and 1D SGTR modeling. The primary side was modeled as pipe component. The secondary side was modeled as Multi-D component and connected by a heat structure. If a tube is ruptured, primary coolant flows into the secondary side. In order to simulate this situation, two valve junctions connecting a primary side and a secondary side were introduced. Tube rupture simulations are achieved by opening the valve junction at a steady-state problem. Figure 2 shows rupture location that locates the middle of hot-leg side tube sheet.

2.3. Results

In this study, in order to verify the differences between 1D and Multi-D modeling, the steady-state problem was previously calculated before the SGTR event simulation of APR1400. Figure 3 shows the void fraction of secondary at steam generator for Multi-D modeling. In this figure, it shows that void fraction is different between hot-side and cold-side.

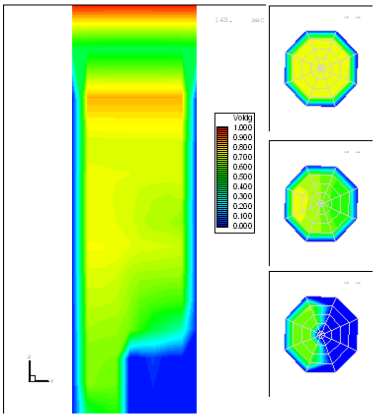
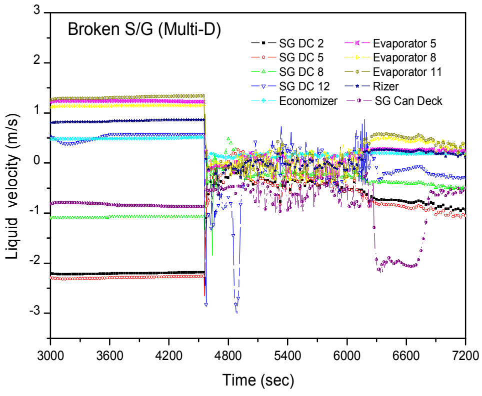
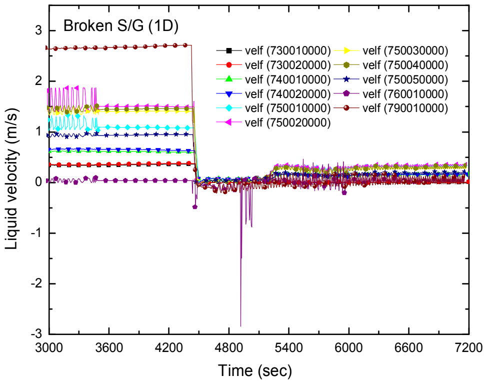


Figure 3. Void fraction of secondary side at steam generator.

The SGTR event of APR1400 design was simulated and analyzed by using Multi-D component modeling. Figure 4 shows the calculated results compared with those of 1D and Multi-D for representative case.



(a) Multi-D modeling.



(b) 1D modeling.

Figure 4. Comparison of liquid velocity.

As shown in figure 4, the liquid velocity both cases shows slightly changed until about 4500s after the tube rupture. However, the liquid velocity in the case of 1D after the reactor trip at 4500s shows generally stagnant except the S/G can deck because of both the reactor trip and main feedwater system termination. While, the velocity in the case of Multi-D shows oscillated after the reactor trip.

3. Conclusion

The SGTR event of APR1400 was simulated by using multi-dimensional components in MARS Code and the results were compared with those of 1D modeling. The steady-state results of both 1D and Multi-D modeling show a good agreement with the design data within ±0.1%. error bound. The SGTR event was simulated and analyzed. As a result, during the transient, the major thermal-hydraulic behavior following the SGTR event can be verified through the 1D and Multi-D simulation. It is concluded that MARS Code can be to calculate the Multi-D modeling through the SGTR event.

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