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The Main Steamline Break Transient Analysis for Advanced Boiling Water Reactor Using TRACE, PARCS, and SNAP Codes

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***Abstract*—**To confirm the reactor and containment integrity of the Advanced Boiling Water Reactor (ABWR), we perform the analysis of main steamline break (MSLB) transient by using the TRACE, PARCS, and SNAP codes. The process of the research has four steps. First, the ABWR nuclear power plant (NPP) model is developed by using the above codes. Second, the steady state analysis is performed by using this model. Third, the ABWR model is used to run the analysis of MSLB transient. Fourth, the predictions of TRACE and PARCS are compared with the data of FSAR. The results of TRACE/PARCS and FSAR are similar. According to the TRACE/PARCS results, the reactor and containment integrity of ABWR can be maintained in a safe condition for MSLB.

***Keywords*—**ABWR, TRACE, PARCS, SNAP.

I. Introduction

THE advanced BWR design is ABWR. The ABWR NPP is Generation III NPP. The ABWR NPP is built in Japan and Taiwan (ex. Kashiwazaki Kariwa and Lungmen). Therefore, to study the safety of the ABWR, we use the TRACE, PARCS, and SNAP codes to simulate and analyze some transients.

The TRACE code is the advanced thermal hydraulic code for the safety analysis [1]. According to the TRAC, RELAP5 and other programs, U. S. NRC develops the TRACE code. The PARCS code is the reactor core simulator [2]. The PARCS code can simulate the 3-D or 1-D core. In addition, the PARCS code is capable of coupling the thermal-hydraulics system codes (ex: TRACE, RELAP). Additionally, in this study, using SNAP code, which is a graphic interface code, process the inputs, outputs, and animation models for TRACE and PARCS [3].

The double-ended MSLB transient of the ABWR is chosen to present the case study in this paper. The MSLB transient is the design-basis accident analysis of the containment, presenting in the FSAR Section 6.2 [4]. According to the FSAR 6.2, the double-ended MSLB transient is the limiting case for the DW (drywell) pressure.

This study presents the establishment of the ABWR model by using TRACE, PARCS, and SNAP codes. And the MSLB transient analysis is performed by using this model to confirm the effect of the MSLB in the ABWR. The data of FSAR and the criteria [4] are used to compare the TRACE/PARCS analysis results.

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II. The TRACE/PARCS/SNAP Model

The analysis process of the study is as follows:

- The ABWR data which include the FSAR and reports [4]-[6] are collected.
- The TRACE/PARCS/SNAP model is established by using the above data. This model includes the main components of the NPP and the important control systems.
- The TRACE/PARCS/SNAP model performs the steady state analysis to check the parameters values.
- The TRACE/PARCS/SNAP model performs the analysis of MSLB transient after the steady state analysis finished.
- The predictions of the TRACE/PARCS under the steady state and transient conditions are compared with the FSAR data.

In addition, the assumptions and initial conditions of the MSLB transient analysis are as follows:

- Initial reactor power is 4005 MWt (102% rated power).
- Double-ended MSLB break occurs at 0 s. The broken area of the RPV side is 0.0984 m^2 (flow limiter area). And the broken area of the main steam header side is 0.319 m^2 (main steam line area).
- MSIVs start to close at 0.5 sec and fully close at 5.0 sec after MSLB.
- Initial pressure and temperature of DW are 5.17 kPaG and 57.2 ℃, respectively.
- Initial pressure and temperature of WW (wetwell) are 5.17 kPaG and 35 ℃, respectively.
- The initial SP (suppression pool) level was at 7.1 m from the bottom.

Fig. 1 depicts the TRACE/PARCS/SNAP model of ABWR. This model contains the thermal hydraulic components of TRACE and core components of PARCS. The core components of PARCS include the assembly rotations map and control rod pattern. The thermal hydraulic components of TRACE include the reactor, RIPs, steam lines, feedwater, turbine, containment, etc. In addition, the DW can be divided into the UDW (upper drywell) and LDW (lower drywell).

III. Results

First, to check the parameters values of the model, the steady state analysis is performed in this study. Table I lists the comparison results of the TRACE/PARCS and FSAR data [4] for the steady state analysis. Table I shows that the analysis results of TRACE/PARCS and FSAR are similar. After the steady state analysis is finished, the MSLB transient is simulated and analyzed.

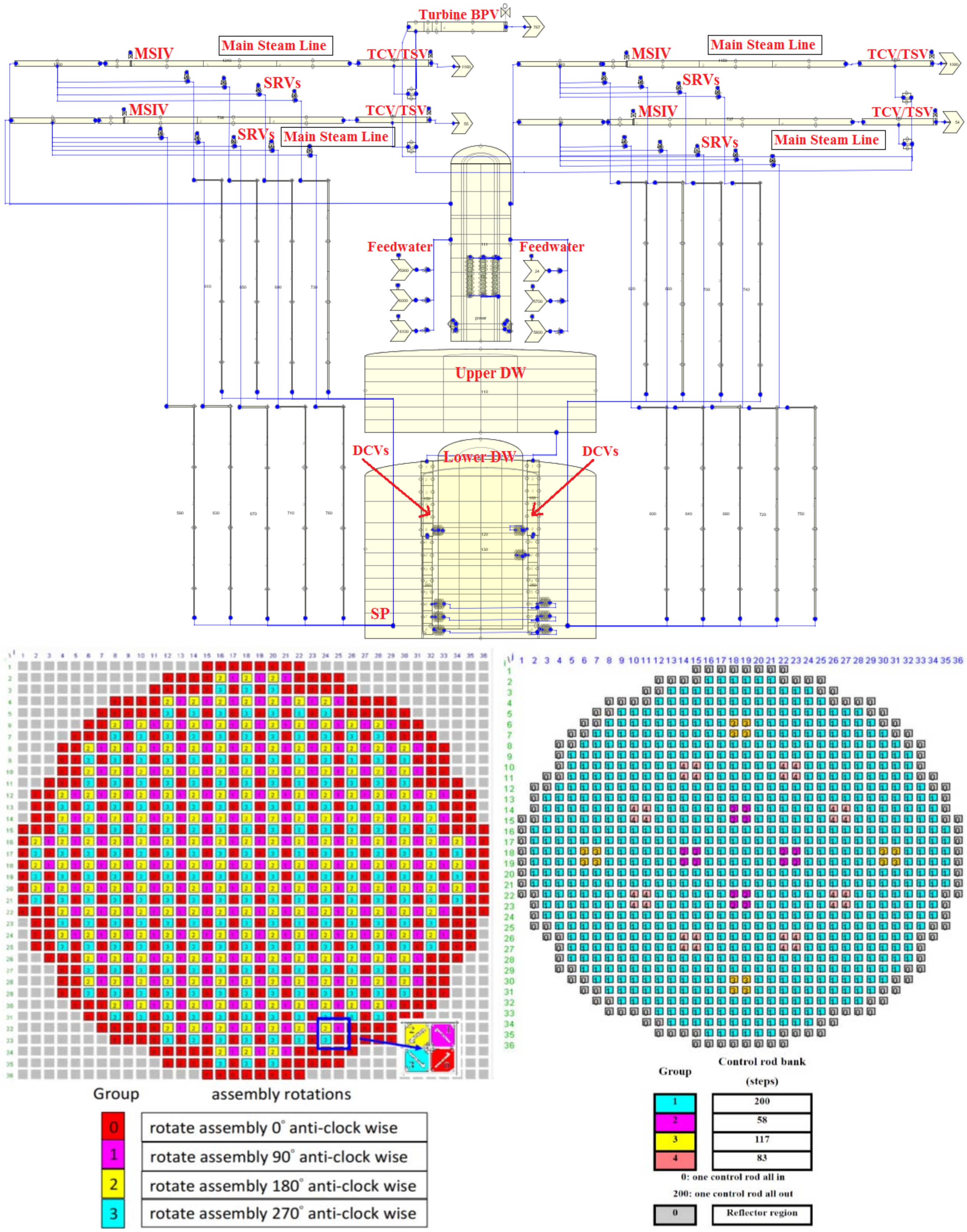

Fig. 1 The TRACE/PARCS model of Lungmen ABWR

TABLE I
THE COMPARISON OF INITIAL CONDITIONS BETWEEN FSAR AND TRACE/PARCS

Parameters	FSAR	TRACE /PARCS	Difference (%)
Power (MWt)	3926	3926	0
Dome pressure (MPa)	7.1705	7.1244	-0.65
Narrow range water level (m)	1.19	1.19	0
Steam flow (kg/sec)	2122	2113	-0.4
Feedwater flow (kg/sec)	2122	2113	-0.4
Core flow (kg/sec)	12314.8	12343.6	0.2

Figs. 2-8 show the analysis results of TRACE/PARCS and FSAR for the MSLB transient. Figs. 2 and 5 depict the pressure and temperature responses of the UDW. Figs. 3 and 6 present the pressure and temperature responses of the LDW. The TRACE/PARCS analysis results show the same trends with the FSAR data, but both pressure and temperature transfer delay-times are longer than the FSAR. That is because the FSAR analysis, for conservative assumption, assumes the DW volume to be the sum of UDW and 50% LDW. Therefore, the transmissions of the pressure and temperature in the FSAR are faster than the TRACE/PARCS. In addition, both pressure and temperature of the DW decrease after a large amount of liquid water blow down into the DW. Moreover, in the FSAR analysis, the results of the UDW and LDW are the same because the FSAR treats the UDW and LDW as one volume.

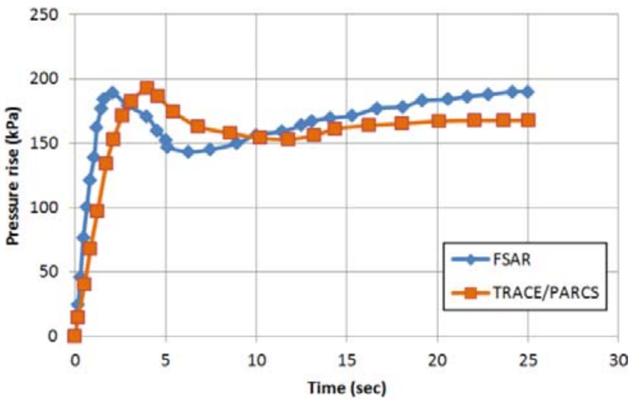

Fig. 2 The pressure rise results of UDW

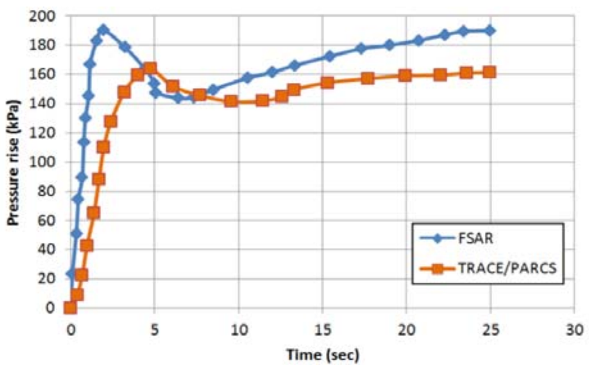

Fig. 3 The pressure rise results of LDW

Figs. 4, 7 and 8 present the pressure and temperature responses of the WW and SP. The TRACE/PARCS analysis results imply the same trends with the FSAER data except the WW airspace temperature. Because the FSAR assumes the WW to be homogeneous mixture and steam to be completely condensed by the SP, these result in the difference in the WW airspace temperature.

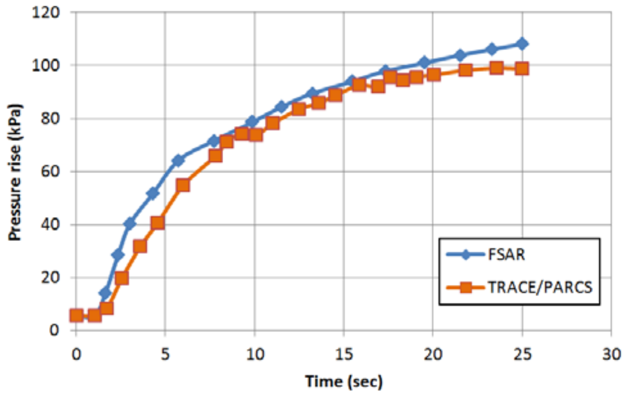

Fig. 4 The pressure rise results of WW

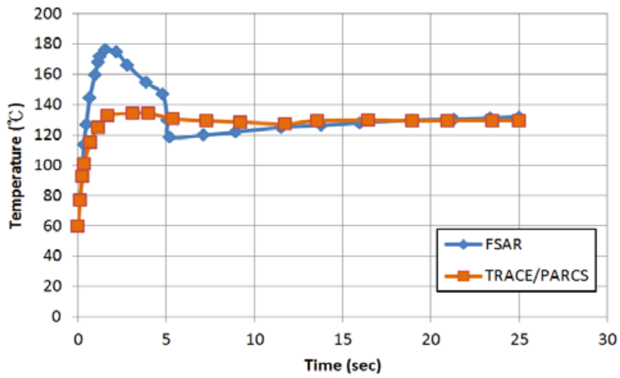

Fig. 5 The temperature results of UDW

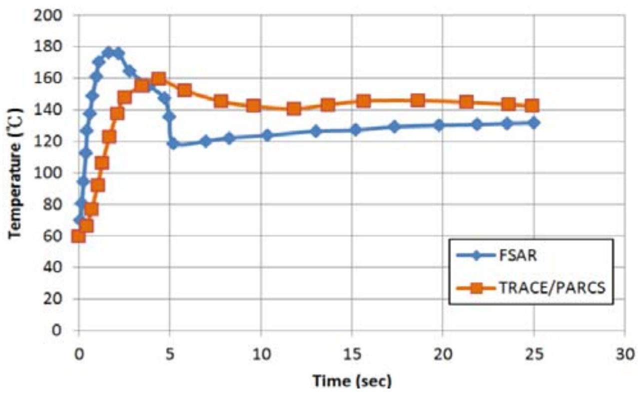

Fig. 6 The temperature results of LDW

Additionally, this study also compares the predictions of the TRACE/PARCS and criteria [4]. According to the TRACE/PARCS analysis results, the peak of the dome pressure is 7.03 MPaG (the criteria is 10.342 MPaG); the peak of the pressure and temperature of the DW are 192.44 kPaG and 158.82 ℃ (the criteria is 309.9 kPaG and 171.1 ℃ , respectively); the peak of the WW pressure, WW airspace temperature, and SP temperature are about 100 kPaG, 80 ℃ and 38 ℃ (the criteria are 309.9 kPaG, 97.2 ℃ ,and 124.0 ℃, respectively). And the peak of the DW-WW pressure difference is 130.561 kPaD (the criteria is +172.6 kPaD). In summary, the results of TRACE/PARCS are below the criteria.

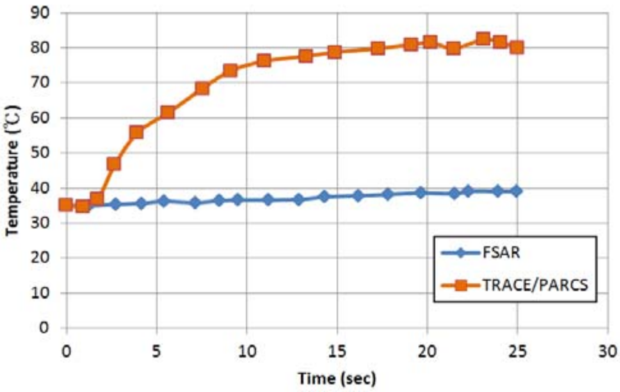

Fig. 7 The temperature results of WW airspace

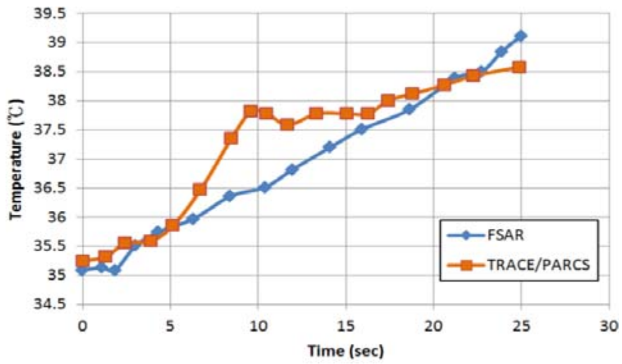

Fig. 8 The temperature results of SP

IV. Conclusion

This research established the TRACE/PARCS/SNAP model of ABWR by using TRACE, PARCS, and SNAP codes. This ABWR model analyzed the MSLB transient to confirm the reactor and containment integrity. And the analysis results of TRACE/PARCS coupling calculation are compared with the FSAR data. The trends of TRACE/PARCS and FSAR for the parameters are similar. According to TRACE/PARCS calculation, the results and criteria are as follows: the peak of the dome pressure is 7.03 MPaG (10.342 MPaG for criteria); the peak values of pressure and temperature in the DW are 192.44 kPaG and 158.82 ℃ (309.9 kPaG and 171.1 ℃ for criteria, respectively); the peak values of the WW pressure, WW airspace temperature, and SP temperature are about 100 kPaG, 80 ℃ and 38 ℃ (309.9 kPaG, 97.2℃ and 124.0℃ for criteria, respectively). And the peak difference of DW-WW pressure is 130.561 kPaD (+172.6 kPaD for criteria). Both reactor and containment integrity criteria are met according to the above results.

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