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Using TRACE, PARCS, and SNAP Codes to Analyze the Load Rejection Transient of ABWR

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***Abstract*—**The purpose of the study is to analyze the load rejection transient of ABWR by using TRACE, PARCS, and SNAP codes. This study has some steps. First, using TRACE, PARCS, and SNAP codes establish the model of ABWR. Second, the key parameters are identified to refine the TRACE/PARCS/SNAP model further in the frame of a steady state analysis. Third, the TRACE/PARCS/SNAP model is used to perform the load rejection transient analysis. Finally, the FSAR data are used to compare with the analysis results. The results of TRACE/PARCS are consistent with the FSAR data for the important parameters. It indicates that the TRACE/PARCS/SNAP model of ABWR has a good accuracy in the load rejection transient.

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

I. Introduction

THE important work of NPPs are the safety analysis of transients. To analyze the transients of NPPs by using computer codes can maintain and increase the NPPs safety. The TRACE code is an advanced thermal hydraulic code [1] and is developed by U.S. NRC. According to TRAC, RELAP5, and other programs, U.S. NRC develops the TRACE code. TRACE has the 3-dimensional (3-D) geometry vessel component. This can provide the more detailed safety analysis. The PARCS code is the multi-dimensional core simulator [2] for the reactor. The PARCS code includes a 3-D model for the realistic representation of the reactor core while 1-D modeling features are also available. The PARCS code is capable of coupling the thermal-hydraulics system codes such as TRACE, RELAP5, and so on. The SNAP code is a graphic interface code and can handle the inputs, outputs, and animation models for TRACE and PARCS [3].

Advanced Boiling Water Reactor (ABWR) is a Generation III nuclear plant. Japan and Taiwan have the ABWR NPP. This research focuses on the establishment of the ABWR model and the analysis of load rejection transient by using TRACE, PARCS, and SNAP codes. The FSAR data [4] from the Lungmen NPP in Taiwan are used to compare the results of TRACE/PARCS.

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II. The TRACE/PARCS/SNAP Model

The flowchart of the analysis methodology for ABWR is shown in Fig. 1. First, the systems, operating data, and FSAR [4]-[6] for the ABWR are collected. Second, several important control systems are established by SNAP and TRACE. Third, some necessary components are added into the TRACE/SNAP model. Fourth, the CASMO-4 code is used to carry out the lattice calculations. The CASMO-4 results are used to establish the PARCS/SNAP model. Then, the TRACE/SNAP model is coupling with the PARCS/SNAP model. Finally, the TRACE/PARCS/SNAP model perform the the steady state and transient calculations. The FSAR data are used to compare with the TRACE/PARCS results.

The TRACE/PARCS/SNAP model of ABWR is presented in Fig. 2. The vessel which simulates the reactor is divided into 11 axial levels, four radial rings, and six azimuthal sectors. This vessel connects with four steam lines, six feedwater lines, 10 RIPs, and 18 channels. The channel components simulate the fuel region which includes the water rods and partial length rods simulation. The steam lines have main steamline isolation valves (MSIVs) and safety relief valves (SRVs). Fig. 2 also presents the containment which includes the DW (drywell), SP (suppression pool), and DCVs (drywell connecting vents). In addition, the PARCS code simulates the assembly rotations map and control rod pattern in this research.

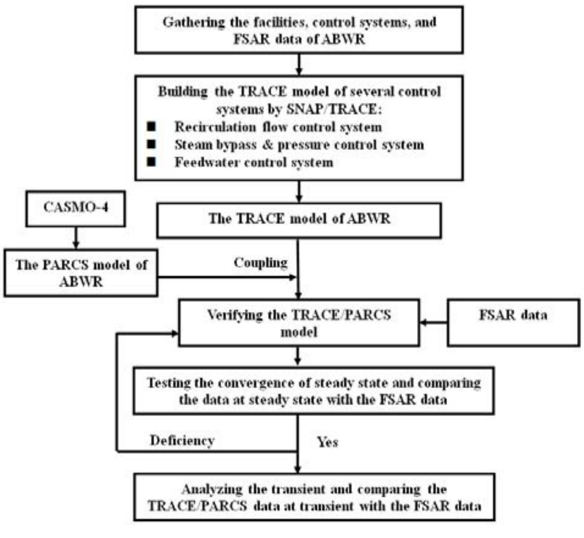

Fig. 1 The flowchart of the analysis methodology for ABWR

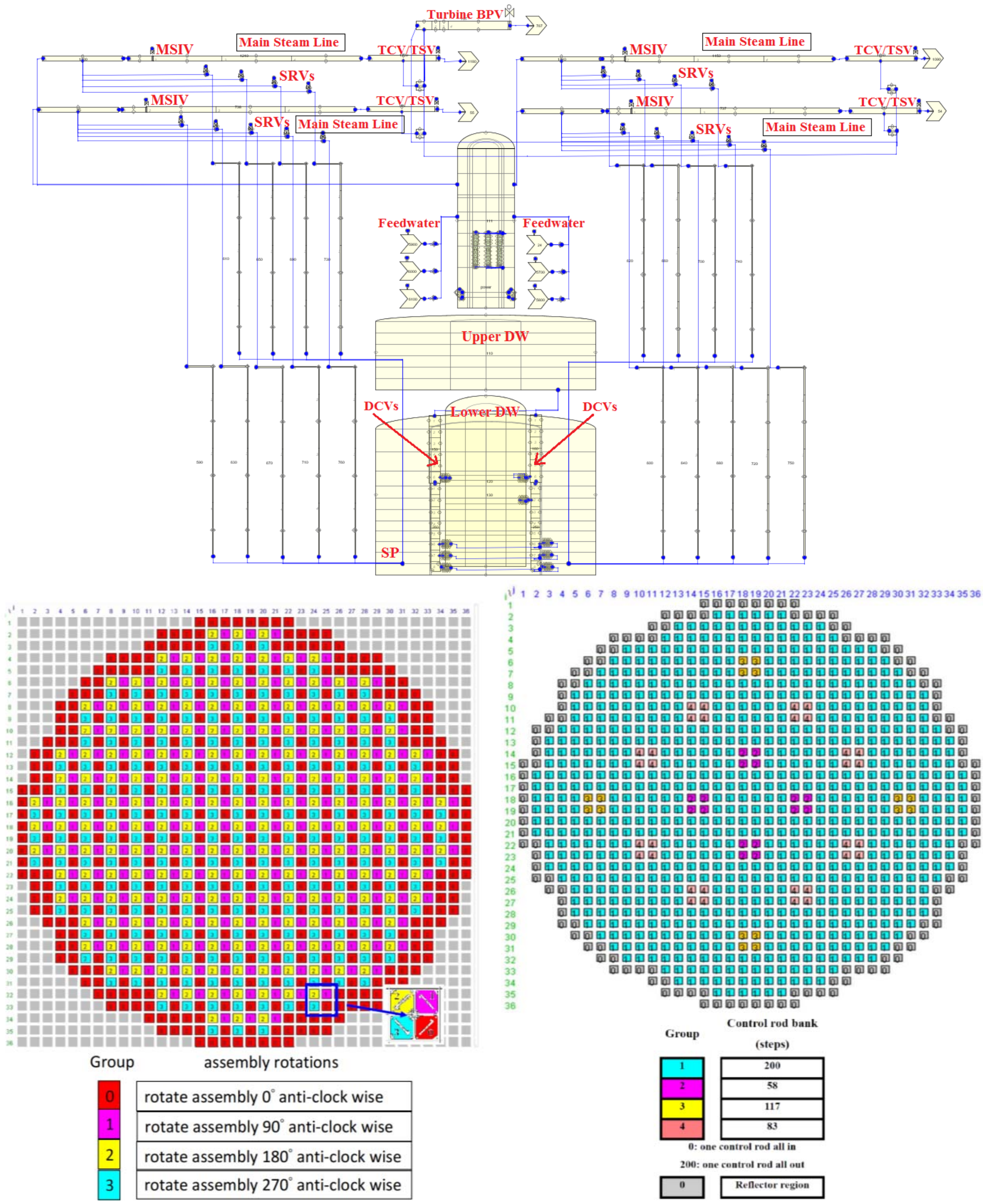

Fig. 2 The TRACE/PARCS/SNAP model of ABWR

III. Results

The steady state calculation is necessary to perform to make sure that the system parameters of the model are consistent with FSAR data [4] before the transient calculation begins. These parameters include power, steam flow, NRWL (Narrow Range Water Level), dome pressure, feedwater flow etc. Table I shows the comparisons of steady state between the results of TRACE/PARCS and FSAR. The TRACE/PARCS results agree well with FSAR in the steady state condition. Then, the load rejection transient was simulated and analyzed by using TRACE/PARCS/SNAP model.

The load rejection transient is used to check the TRACE/ PARCS/SNAP model to confirm the turbine control valves (TCVs) capability and the system response of the model. The initial condition of load rejection transient is 100% rated power/85% rated core flow. First, the fast closure of the TCVs is performed whenever electrical grid disturbances which cause significant loss of electrical load on the generator happen. The TCVs are required to be closed as soon as possible to avoid the excessive overspeed of the turbine-generator rotor. The closure of the TCVs may result in a sudden reduction in the steam flow of the turbine, which causes an increase in the pressure of the system if the bypass valves fail to open. Then, in order to defend the reactor, the scram of the reactor and the trip of four RIPs are initiated because the failure of all bypass valves occurs.

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

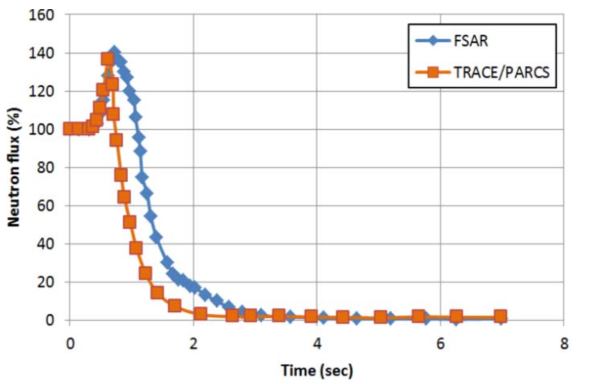

Fig. 3 The neutron flux results

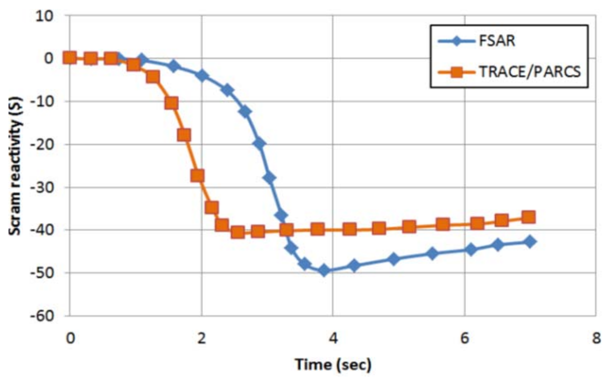

Fig. 4 The scram reactivity results

TABLE II
THE SEQUENCES OF FSAR AND TRACE/PARCS

Action	Time (sec)	
	FSAR	TRACE/PARCS
Generator load rejection with failure of all bypass valves	0	0
Turbine control valves closed	0.076	0.076
Scram initiated	0.40	0.40
Four RIPs tripped	0.49	0.49
Safety/relief valves opened due to high pressure	2.6	2.56

Table II shows the load rejection transient sequences of FSAR and TRACE/PARCS. The sequence of TRACE/ PARCS is very similar to the FSAR data. Figs. 3 ~ 6 present the results of TRACE/PARCS and FSAR. Fig. 3 shows the neutron flux results of FSAR and TRACE/PARCS. The curve of TRACE/PARCS is consistent with the FSAR data. The closing of the TCVs results in the decrease of the reactor void. Then, the positive reactivity generates which causes the increase of the neutron flux. Subsequently, the reactor scram occurs which results in the decrease of the neutron flux. The dropped time of the neutron flux for TRACE/PARCS is earlier than FSAR data, which is also observed in Fig. 3. The difference of the scram reactivity between TRACE/PARCS and FSAR may be the reason for the above results. Fig. 4 depicts the scram reactivity results of FSAR and TRACE/ PARCS. Due to the different motion speed of the control rods insertion between FSAR and TRACE/PARCS, the scram curve of TRACE/PARCS would not be totally consistent with the FSAR data. Additionally, the trend of Doppler reactivity for TRACE/PARCS is also similar to the FSAR data, but their void reactivity has the difference. The difference on the calculation of void fraction of TRACE/PARCS and FSAR may result in the different void reactivity. The dome pressure results of FSAR and TRACE/PARCS is presented in Fig. 5. Their curves are approximately in agreement. The closing of the TCVs makes the increase of the dome pressure. Subsequently, the relief valves open and cause the decrease of the dome pressure. The dome pressure prediction of TRACE/ PARCS is smaller than the FSAR data after 3 sec. This implies that the void fraction of the core may increase. But, the feedwater flow also increases at this time which causes the larger cooler water into the core of the reactor. This indicates that the void fraction of the core may decrease. According to the above effects, the void fraction of the core still decreases slower after 3 sec. And this cause the void reactivity also increases slower. The prediction of TRACE/PARCS is similar to this phenomenon. Fig. 6 presents the core flow results of TRACE/PARCS and FSAR. Because the dome pressure goes up, this causes that the core flow increases before 0.49 sec. Then, four RIPs trip causes the decrease of the core flow. The results of FSAR and TRACE/PARCS are also in agreement on the comparison of the other parameters (such as the feedwater flow, steam flow, narrow range water level, etc.). In summary, the TCVs capability and the system response of TRACE/ PARCS/SNAP model can be observed in the load rejection transient. The comparison results of TRACE/PARCS and

FSAR also indicates that there is reasonable response of the TRACE/PARCS/SNAP model of ABWR in the load rejection transient.

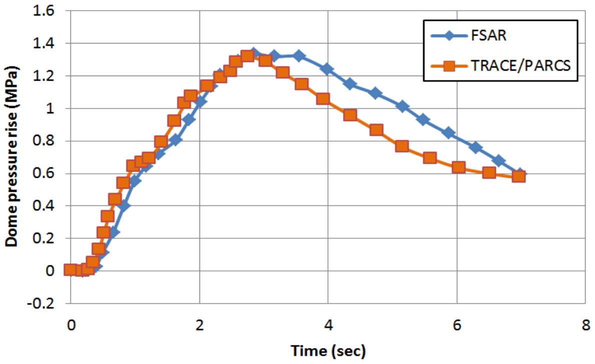

Fig. 5 The dome pressure rise results

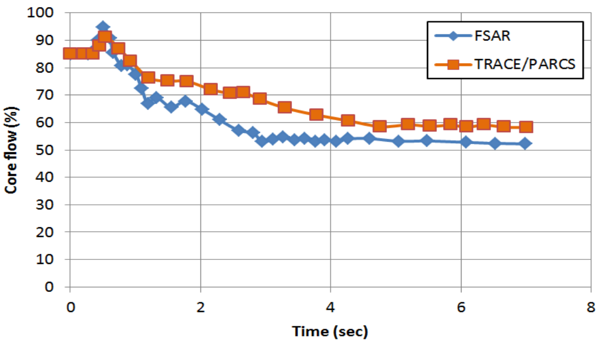

Fig. 6 The core flow results

IV. Conclusion

This study has established the analysis methodology and the TRACE/PARCS/SNAP model of ABWR by using TRACE, PARCS, and SNAP codes. This TRACE/PARCS/SNAP model analyzed the load rejection transient to confirm the dynamic response of the model and demonstrate the TCVs capability. The predictions of TRACE/PARCS present that the TRACE/PARCS/SNAP model of ABWR can predict the behaviors of important parameters. And it also implies that the analysis results have the similar trends with FSAR data. This depicts that the TRACE/PARCS/SNAP model of ABWR has a good accuracy in the load rejection transient. Therefore, this TRACE/PARCS/SNAP model can be applied to perform other transient analysis with confidence.

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