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The feedwater control system and steam dump control system responses during large-load reduction transient for Maanshan PWR Plant

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Abstract

In this study, the development of TRACE (TRAC/RELAP Advanced Computational Engine) models for Maanshan nuclear power plant (NPP) important control systems, such as feedwater control system and steam dump control system, are performed in using SNAP (Symbolic Nuclear Analysis Program) / TRACE. The large-load reduction transient analysis of the Maanshan NPP control system TRACE models are also performed and the responses of the control systems of TRACE models compare with Maanshan NPP startup tests data to verify their accuracy. Analysis results of TRACE indicate that the responses of the Maanshan NPP control system TRACE models are consistent with the plant data for large-load reduction transient.

Keywords: TRACE; PWR; control system.

1. Introduction

In the NPP safety, the safety analysis of the NPP is very important work. In general, the NPP safety analysis is performed by the thermal hydraulic codes. The advanced thermal hydraulic code named TRACE for the NPP safety analysis is developing by U.S. NRC [1]. The development of TRACE is based

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on TRAC, integrating RELAP5 and other programs. In the future, NRC has determined that TRACE will be the main code used in thermal hydraulic safety analysis, and no further development of other thermal hydraulic codes such as RELAP5 and TRAC. SNAP, a graphic user interface program, which processes inputs and outputs for TRACE is also under development. To model the reactor vessel with 3-D geometry is one of the features of TRACE. It can support a more accurate and detailed safety analysis of NPPs.

Taiwan and U.S. have signed an agreement on CAMP（Code Applications and Maintenance Program） which includes the development and maintenance of TRACE. INER (Institute of Nuclear Energy Research Atomic Energy Council, R.O.C.) is the organization in Taiwan that is responsible for the application of TRACE in thermal hydraulic safety analysis, for recording users' experiences of it, and providing suggestions for its development. To meet this responsibility, it has built a TRACE model of TPC (Taiwan Power Company) Maanshan PWR NPP.

In this study, TRACE models of Maanshan NPP control systems such as feedwater control system and steam dump control system, were developed first. The large-load reduction transient analysis of the control system TRACE models is also performed. Finally, the responses of the control system TRACE models for Maanshan NPP are compared with the Maanshan NPP startup tests data [2]-[3].

2. The Maanshan NPP control system TRACE models

(a) Feedwater control system

Figure 1 shows the TRACE model of the feedwater control system in the Maanshan NPP. The model was established according to the report of INER [2]-[3]. The main function of the feedwater control system is to maintain a fixed water level of the steam generator in the secondary side when it is operating normally. The feedwater control system controls the main feedwater control valve using three signals, (1) the water level error signal, (2) the steam flow signal, and (3) the feedwater flow signal. The water level error signal is calculated as the difference between the actual water level and the preset water level (typically 50%). Another value is calculated as the difference between the steam flow and the feedwater flow. These two differences are taken as the control signals of feedwater valve. The TRACE model of the feedwater control system was verified with the large-load reduction data of Maanshan NPP.

(b) Steam dump control system

The steam dump control system is composed of ten atmospheric venting valves, six turbine bypass valves and the associated piping control apparatus. Figure 2 shows the TRACE model of the steam dump control system. This model was established mainly as described in the report of INER [2]-[3]. The ten atmospheric venting valves and six turbine by-pass valves are grouped into four sets in this model: three turbine bypass valves comprise the first set; the other three are formed as the second set; five atmospheric venting valves are considered as the third set, and the fourth set consists of the rests.

When a turbine trip occurs, an electrical signal that is converted from the error signal between the highest Tavg and Tnoload is sent to the turbine trip controller. Through the P/I controller, air that flows from the air supply piping is directed to the first and second sets of turbine bypass valves to control their degree of opening.

For load rejection of load reduction, an electrical signal that converted from the error signal between the highest Tavg (maximum) and Tref (converted from first-stage steam pressure) is sent to the load rejection controller. Through the P/I controller, air that flows from the air supply piping is directed to the turbine bypass valves and atmospheric venting valves (the first through fourth sets of valves) to control their degree of opening. The TRACE model of the steam dump control system was confirmed using the large-load reduction data of Maanshan NPP.

3. Results

(a) Feedwater control system

Figure 3 shows the steam flow and water level Maanshan NPP data of the large-load reduction test. These data are inputted into the feedwater control TRACE model of Maanshan NPP. Then, the feedwater flow can be obtained by the calculation of the feedwater control system TRACE model. Figure 4 compares the feedwater flow of the TRACE model and the Maanshan NPP data. The TRACE curve is almost the same with the measured values of Maanshan NPP. The above result indicates that the feedwater control TRACE model of Maanshan NPP can calculate the feedwater flow accurately.

(b) Steam dump control system

Figure 5 compares the results of the TRACE model with Maanshan NPP data; they generally agree closely. Notably, in Figs. 5(a) and 5(b), the first and second sets of valves were closed at 375s and remained closed during testing. However, the simulated results of TRACE indicate that the first and second sets of valves open again. The temperature difference from the plant testing records reveals that the first and second sets of valves should have open again. Hence they are suspected to have been manually closed during the test. Figure 5(b) demonstrates that the valve opening in TRACE reduces to 0% (200s to 400s), but was in fact about 4.5% in the plant data. In the steam dump control system, Tavg signal activates the valves. All of the second set of valves should close, according to the Tavg difference records, but in fact, they close only to around 4.5%. Therefore, the second set of valves could not be fully closed or were poorly calibrated in the testing process. The results for the steam dump control system obtained using the TRACE model are thus concluded to agree closely with the plant data.

4. Conclusion

By using SNAP/TRACE, this study developed the feedwater and steam dump control system TRACE models of the Maanshan NPP. Effectiveness of the proposed models was verified with large-load reduction transient data of Maanshan startup tests. Analytical results indicate that the Maanshan TRACE models predicts in consistent trends with the plant data.

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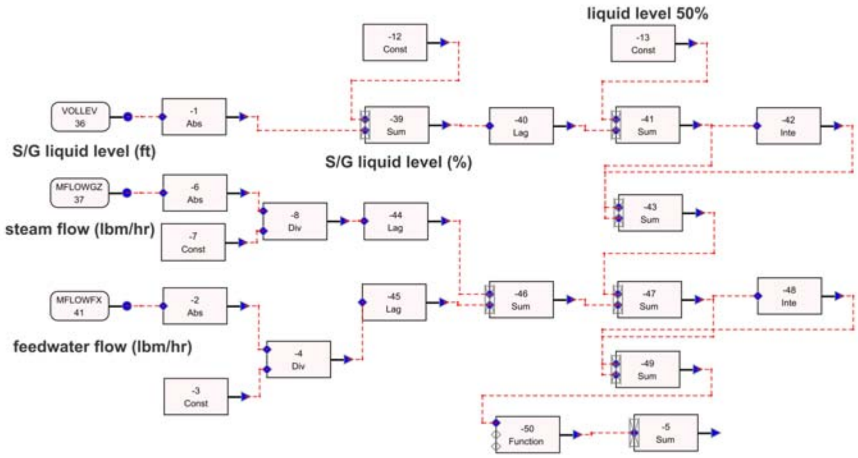

Fig. 1. The feedwater control system TRACE model of Maanshan NPP.

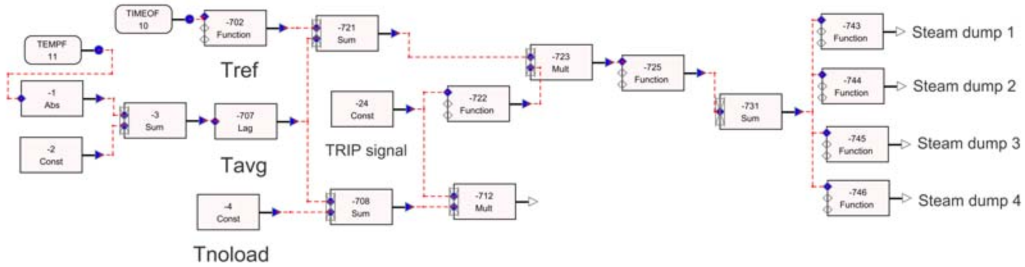

Fig. 2. The steam dump control system TRACE model of Maanshan NPP.

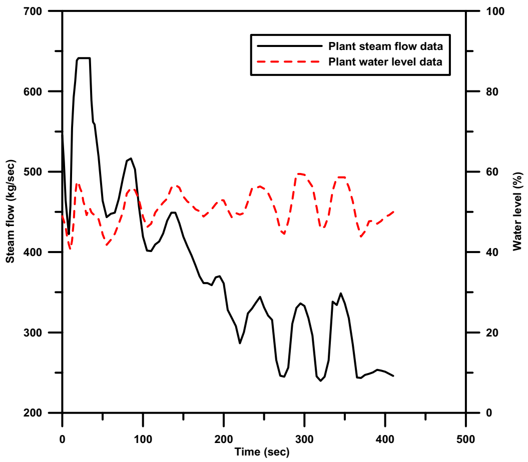

Fig. 3. The steam flow and water level data of Maanshan

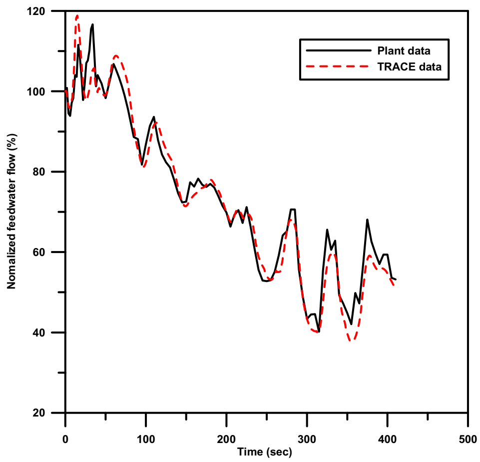

Fig. 4. The TRACE results of feedtwater flow control system

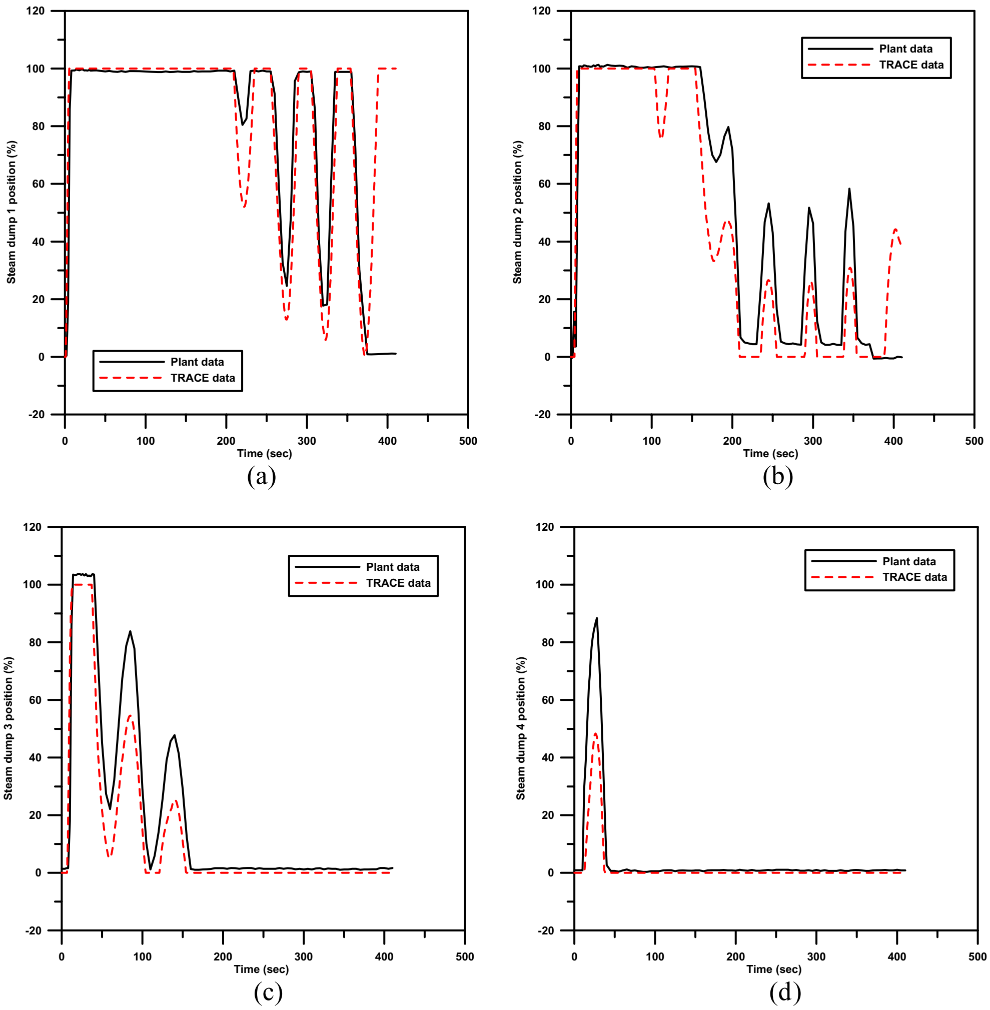

Fig. 5. The TRACE results of steam dump control system: (a) first set; (b) second set; (c) third set; (d) fourth set.