Comparative Study on RELAP5 and TRACE code for OPR-1000 LBLOCA

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1. Introduction

RELAP5 and MARS-KS codes have been used for regulatory audit calculation of Large-Break Loss of Coolant Accident (LBLOCA) of Light Water Reactors (LWR). Also, US NRC's TRACE Ver5 Patch3 code has been developed for consolidation of two thermal-hydraulic codes, RELAP5 and TRAC. [1] As a part of research project 'Development of Regulatory Audit Technology for System Safety of Sodium-cooled Fast Reactors (SFR)', the applicability of TRACE code to the safety analysis of SFR has been evaluated by KINS since 2012. [3]

In the present study, an input deck of TRACE code was developed based on RELAP5 input deck for LBLOCA of the Optimized Pressurized water Reactor (OPR) 1000MWe, and the results from both code calculations were compared. On a result of this study, further study needs were identified in TRACE code application of LWR accident calculations and the applicability to SFR's design base accident was reviewed in the function of steady-state calculation, Trip and controls etc.

2. Methods and Results

RELAP5/MOD3.3 input data of OPR-1000 type ULJIN Units 3 /4 was selected to develop input deck for TRACE Ver.5 patch3 since it has been used for audit calculation of LBLOCA. [4]

In order to minimize errors converting in geometry of nodes, controls, settings, etc, into TRACE. RELAP / TRACE conversion function of SNAP program was used.

2.1 Development of TRACE code input data

In developing of TRACE code input deck for OPR-1000 LBLOCA, the following process was carried out under SNAP program environment.

1) Import of RELAP5 steady-state input deck to SNAP program
2) Automatic conversion to TRACE deck with R2TRACE plugin
3) Debugging of the converted TRACE input deck
4) Adjustment of the steady-state deck comparing with RELAP5 steady-state result and the plant design condition
5) Transient TRACE deck development based on the RELAP5 LBLOCA transient deck

SNAP program has useful functions regarding of pre-processing and post-processing such as input creation and modification, calculation, value extraction and graphing including batch processing on the graphical user interface. Conversion of RELAP5 based input to TRACE also possible in SNAP.

The result of the conversion using the SNAP Ver. 2.2.2 did not shows any problems in terms of the thermal-hydraulic nodes, heat structures and control variables. But, converting reactor kinetics model in RELAP5 input showed a need to be improved and user's manual conversion was needed.

On the debugging of the converted TRACE steady state input, it was found that the PIPE component conversion from Branch and Single Junction components in RELAP5 input invoked the elevation mismatch and that additional adjustment of K-factor was needed. Especially, the Separator of Steam Generator (SG) and Accumulator components modeling were needed to improve.

2.2 Comparison of steady-state calculation results

Mass flow rate of the primary loop and the feed water, the level of the pressurizer and the pressure of the primary loop reached their design conditions successfully. TRACE code calculated a little higher pressure and the water level in the SG than the design conditions.

For the secondary pressure and the water level in the SG, the difference between two calculations was due to the modeling adjustment of SG. The calculated steady-state condition of both codes are compared in Table I

Table I: Steady state conditions of TRACE and RELAP5 codes.

Parameter	RELAP5	TRACE
Power	2,815MW	2,815MW
Primary Flow	15,308kg/s	15,309kg/s
Primary Press.	15.51MW	15.51MW
Pump Speed	130.19rad/s	130.14rad/s
PRZ Level	5.35m	5.38m
SG Press.	7.28Mpa	7.59Mpa
SG Level	9.74ft	10.8ft
SG Feed	735.58/81.73	735.58/81.73
Hot Leg T.	600.75K	600.89K
Cold Leg T.	569.67K	569.72K

2.3 Comparison of LBLOCA calculation results

TRACE transient input data was developed based on the steady-state input and the important feature of RELAP5 transient input. And adjustment was made to develop consolidate input for both of steady-state and transient calculation. Finally its transient calculation was compared with RELAP5's result.

Comparison showed that TRACE predicted higher break flow and higher pump speed of the broken loop than the RELAP5 result during its costdown phase after the pumps trip as shown in Figure 1.

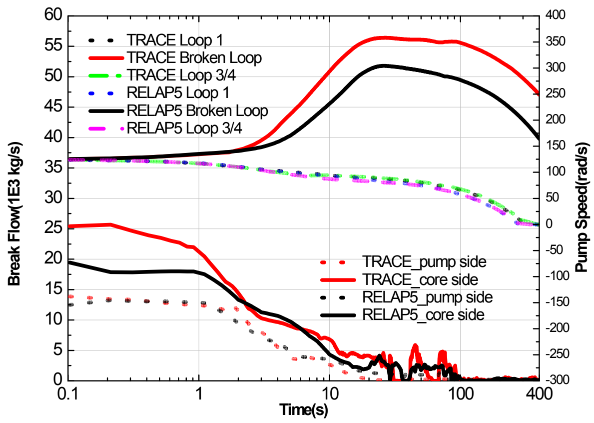

Fig. 1. Break flow and pump speed calculation of TRACE and RELAP codes

Both code predicted core mass flow decrease until 2 seconds. RELAP5 code predicted the down-flow at the top of core after 5 seconds. Otherwise, TRACE code predicted high up-flow before 5 seconds and the Clad Temperature (CT) was decreased slightly by this up-flow and also predicted down-flow from 10 seconds and ended about 30 seconds. Coolant flowing on top of core was almost saturated temperature

RELAP5 code predicted the sharp decrease of the CT from 5 to 11 seconds by the down-flow. Similar down-flow was predicted from 10 to 13 seconds by TRACE code, but the CT was not decreased sharply as shown in Figure 2.

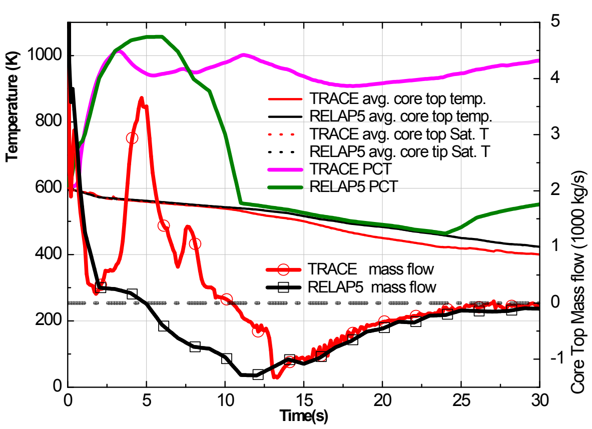

Fig. 2. Mass flow and temperature prediction of RELAP5 and TRACE codes at the top of core during refill phase

Regarding the PCT, TRACE predicted slightly lower blowdown PCT and higher reflood PCT than RELALP5 code as shown in Fig. 2.

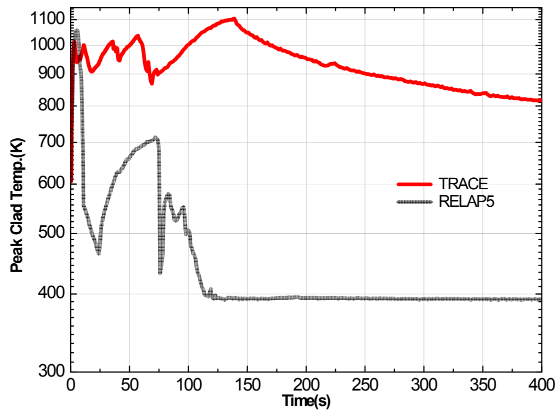

Fig. 3. TRACE and RELAP code PCT prediction

Analysis showed that the predicted PCT of TRACE code was less impacted than RELAP5 by down-flow of the water slug in upper head during blowdown phase, so called "Blowdown Quenching". Since the hot rod of the core was not quenched well during refill phase, TRACE predicts higher reflood PCT after all.

3. Conclusions

As a part of assessment of applicability of TRACE code to SFR safety analysis area, LBLOCA transient case input was developed based on RELAP5 input deck and compared with RELAP5 code's prediction.

Comparison result showed that Blowdown Quenching was not predicted in TRACE calculation significantly and that was most different result from RELAP5 calculation. Since the hot rod was not quenched well during refill phase, TRACE predicts higher reflood PCT after all.

The capability of TRACE code could be used for calculation of steady-state condition and verification of controls during the transients and DBAs for SFRs, where the coolant boiling was not expected.

For more accurate transients, validation with experiments using sodium as a coolant is needed.

REFERENCES

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