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Improvement of the NSSS T/H Module ARTS for Enhancing the Simulation Fidelity of YGN #1/2 Simulator

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1. Introduction

KEPRI(Korea Electric Power Research Institute) and KAERI(Korea Atomic Energy Research Institute) developed a NSSS (Nuclear Steam Supply System) T/H (Thermal-Hydraulic) module (named ARTS) based on the best-estimate code RETRAN-3D [1] for the KNPEC-2 full-scope simulator in 2001 [2]. Although ARTS can simulate the most transients in real-time, and its robustness is ensured, real-time calculation and robustness can fail for large break loss-of-coolant accident (LBLOCA) and long term, two-phase transients. In order to improve its robustness, ARTS equipped with the backup calculation module to be used whenever a regular ARTS module fails to calculate. When the symptom for the failure of T/H module is detected, the main ARTS module is replaced with the backup module for the calculation of primary and secondary reactor system although most failures of ARTS occur in the calculation of the primary system especially for LBLOCA simulation. The sudden transition from the main ARTS module to the backup module can exhibit the discontinuity of simulation of secondary system on rare occasions. To mitigate the simulation discontinuity, we have improved the backup module of ARTS. The performance of a new approach has been illustrated by the non-integrated standalone test. The improved ARTS module will be incorporated into YGN #1/2 simulator and evaluated its performance in the real simulator environment. This paper presents the brief description of a new backup calculation strategy and the simulation results of LOCA to evaluate the performance of a new backup strategy in standalone test environment.

2. YGN Backup Calculation Strategy

We mitigate the simulation discontinuity during the transition from the original ARTS module to the backup module; a single matrix equation system of the backup module for the entire NSSS has been divided into two equation systems; one for primary system and another for secondary system. Whenever the calculation mode change occurs from the normal mode to backup calculation mode, the cause of transition is examined if the failure comes from the calculation of the primary or the secondary side. When the calculation failure occurs in the primary side calculation, only the calculation of primary side is replaced with the backup module instead of replacing both the primary and the secondary sides. In this case, the calculation for the secondary side is solved by the original ARTS module. This approach ensures a continuous simulation in the trend of the secondary side since the calculation of the secondary system is continuously performed by the main ARTS module. Also we change the node of the steam generator secondary side from the steam dome exit model to the common header exit model. This common header exit model has steam lines and a common header which is interfaced with BOP models.

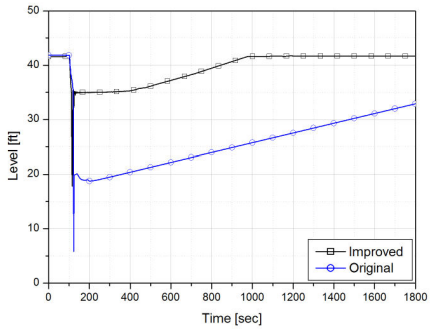

Figure 1. Steam Generator Water levels of the Original & Improved ARTS during 100 % LOCA simulation

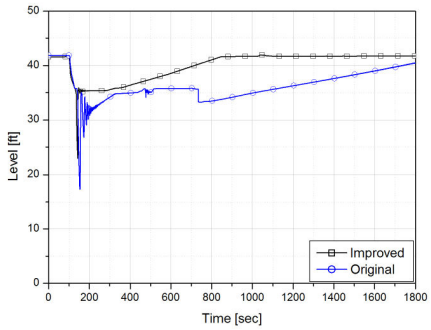

Figure 2. Water levels of the Original & Improved ARTS during 7 % LOCA simulation

3. Simulation Results

In order to evaluate the simulation capability of the improved ARTS module, we have performed the two simulations of LOCA, where the equivalent break sizes are 7 % and 100 % at the cold leg in the loop A, respectively. The LOCA events were initiated by

opening the break valve at 100 seconds in null transient state for both cases. The void fraction in the primary system drastically increases and the pressure of primary system decreases once LOCA occurs. The severe two phase phenomena of the primary system leads to the transition of calculation module and the main ARTS module is finally replaced by the backup module. The transition time of replacement varies inversely as the size of break. In the 1st simulation case, where the equivalent break size is 100 %, the transition of module occurred at 105.95 sec for both of the original and improved ARTS. As expected, the trends of S/G water levels are somewhat different between two cases (See Fig. 1). In the backup model of original ARTS module, the water level is calculated by total amount of fluid mass in the S/G, whereas only liquid volume in the downcomer regions of S/G is considered to calculate the water level in the improved ARTS module. However, because of the shrink of a level due to a turbine trip, the level of S/G falls below the lower level tap which is placed at 34.8 ft from the top of tube sheet during the module transition. Therefore, the operator can not recognize the module change unless he checks a wide range level. In the other hand, for less severe transient, such as 2nd case, the transition of the module may occur later than the severe transient. In this case, the module transition occurred at 422.76 seconds when the water level of S/G was above the lower level tap. As shown in Fig. 2, the level of S/G fell below zero level instantly and this discontinuous level change could confuse the operators and lead them to a wrong operating procedure. But in the improved ARTS module, there was no abrupt change in the S/G water level during the transition and it could reduce the possibilities of misleading operator to a wrong procedure in simulation training. Finally, the abrupt changes in the S/G water level never occurred during LOCA simulations using the improved ARTS module and other system parameters, such as pressure and heat transfer rate are consistent with those of the original ARTS module during the transient simulation.

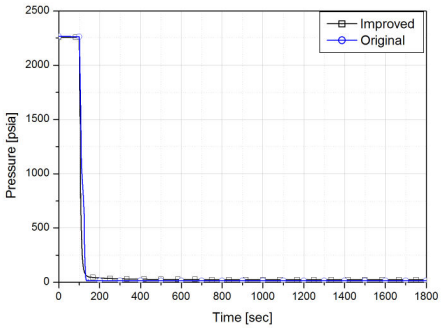

Figure 3. Pressure of the Original & Improved ARTS during 100 % LOCA simulation

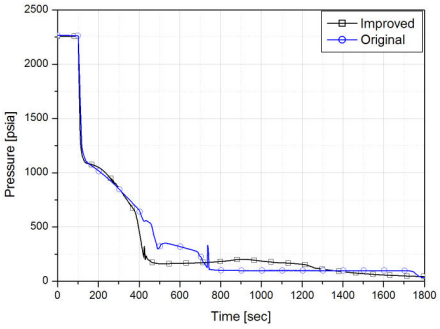

Figure 4. Pressure of the Original & Improved ARTS during 7 % LOCA simulation

4. Conclusion

We mitigate the simulation discontinuity during the sudden transition from the main ARTS module to the backup module, we improved the NSSS calculation module (ARTS) for the YGN #1/2 simulator by separating the single equation system of the backup module for primary and secondary reactor system into two equation system; one for primary system and another for secondary system. The calculation mode has been replaced from the main ARTS module to the backup module for the calculation of primary and secondary reactor system in the previous ARTS module when the symptom for the failure of T/H module is detected. However, the most failures of ARTS occur in the calculation of the primary system especially for LOCA simulation. In these cases, this separation of equation system can ensure the continuous calculation of the S/G secondary side by solving the S/G secondary side using the main ARTS module and replacing the primary system calculation to the backup module. The improvement of a new approach has been proved by the non-integrated standalone test environment. The improved ARTS module will be incorporated into YGN #1/2 simulator and evaluated its performance in the integrated simulator environment.

REFERENCES

[1] F. [1] M. P. Paulsen, et al., “RETRAN-3D Code Manual,” EPRI NP-7450, Electric Power Research Institute, 1998.

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[3] K. D. Kim et al., “Improvement of the NSSS T/H Module for Enhancing the Simulation Fidelity of KNPEC-2 Simulator”, KNS Spring, 2005.