Development of a NSSS T/H Module for the YGN 1/2 NPP Simulator Using a Best-Estimate Code, RETRAN.

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1. Introduction

KEPRI(Korea Electric Power Research Institute) developed a realistic nuclear steam supply system thermal-hydraulic module, named ARTS code, based on the best-estimate code RETRAN for the improvement of the KNPEC(Korea Nuclear Plant Education Center) unit 2 full-scope simulator[1,2,3]. In this work, we make a nuclear steam supply system thermal-hydraulic module for the YGN 1/2 nuclear power plant simulator using a practical application of a experience of ARTS code development.

The ARTS code was developed based on RETRAN[4], which is a best estimate code developed by EPRI(Electric Power Research Institute) for various transient analyses of NPP(Nuclear Power Plants). Robustness and the real time calculation capability have been improved by simplifications, removing of discontinuities of the physical correlations of the RETRAN code and some other modifications. And its scope for the simulation has been extended by supplementation of new calculation modules such as a dedicated pressurizer relief tank model and a backup model. The supplement is developed so that users cannot recognize the model change from the main ARTS module.

2. ARTS-YGN Code Development

RETRAN is a best-estimate transient thermal-hydraulic code designed to analyze operational transients, small break loss-of-coolant accidents, anticipated transients without scram, natural circulation, long-term transients, and events involving limited nonequilibrium conditions in light water reactors. RETRAN, however, has some limitations in real-time calculation capability and its robustness to be used in the simulator for some transient conditions. To overcome these limitations, its robustness and real-time calculation capability have been improved with simplifications and removing of discontinuities of the physical correlations of the RETRAN code. And some supplements are also developed to extend its simulation scope of the ARTS code.

2.1 Nuclear Power Plant Modeling

The target plant for simulator is YGN nuclear unit 1 and 2. YGN 1/2 are a typical Westinghouse, three-loop pressurizer water reactor (PWR) with a rated core power of 2775 MW (thermal) and rated core flow of 28587.23 lb/sec. The reactor coolant system (RCS) consists of a reactor vessel, three inverted U-tube steam generators (SGs), three reactor coolant pumps (RCPs), a pressurizer, and various inter-connecting pipings. Three loops of the RCS are designated loops A, B and C, and pressurizer is connected to loop B. Two pressurizer spray line is connected from cold legs of loop A and loop B.

The RETRAN-3D input model of YGN 1 has been developed for wide-range plant transient and accident analyses under considerations for real-time calculation, robustness and fidelity. The non-homogeneous, non-equilibrium option of RETRAN with algebraic slip was selected for realistic simulation of two-phase flow system. The schematic diagram for plant model is shown in Fig. 1.

2.2 RETRAN Code Modification

Since RETRAN is a generalized code to model the components with control volumes, the smaller time-step size should be used even if converged solution could not get in a single volume. Therefore, dedicated models which do not force to reduce the time-step size are sometimes more suitable in terms of a real-time calculation and robustness[5].

2.3 ARTS Interface Configuration

In order to implement the ARTS code as an NSSS T/H driver for the full-scope simulator, the ARTS module has to communicate with other simulator modules. We developed the interface program for ARTS to communicate with others. The ARTS module calculates an NSSS T/H phenomena based on boundary conditions received from the other simulator modules. ARTS and other modules of simulator are communicated through a global vector. Every module in the simulator writes the calculated values in this vector every 1/12 seconds. ARTS reads the various information from a global vector such as valve opening areas, time-dependent volume pressure, reactor power distribution, etc. and writes all RETRAN global variables, some additional variables which are needed in other modules.

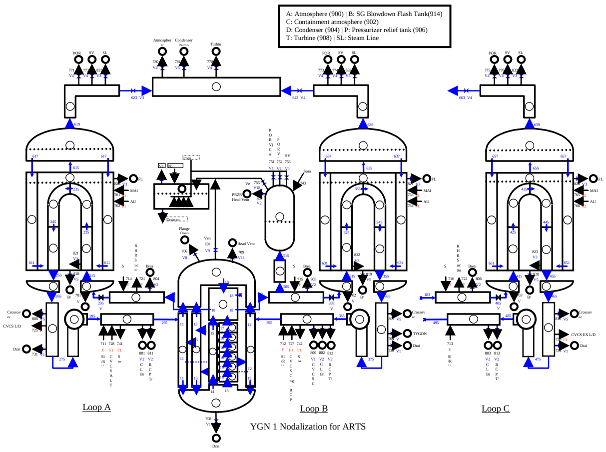

Figure 1. Nodalization for ARTS

3. Conclusion

This paper presents the conceptual basis of a NSSS thermal-hydraulic module for the nuclear power plant simulator. In order to simulate the NSSS T/H model of YGN 1 simulator, we developed an advanced NSSS T/H simulation code, ARTS-YGN, based on a best-estimate code, RETRAN[5]. To make the RETRAN code fit to the simulator, its robustness and real-time calculation capability have been improved with simplifications and removing of discontinuities of the physical correlations of the RETRAN code. Some supplements are also developed to extend its simulation scope of the ARTS code. Since ARTS is a part of simulator modules, ARTS was integrated with 3-D reactor kinetics model and other system models.

The ARTS code guarantees the real-time calculations of almost all transients and ensures the robustness of simulations. However, there are some possibilities of calculation failure in the cases of large break loss of coolant accident (LBLOCA) and low-pressure low-flow transient. The backup calculation system has been developed to substitute automatically the ARTS in this case. The results were reasonable in terms of accuracy, real-time simulation, robustness and education of operators, complying with the ANSI/ANS-3.5-1998 simulator software performance criteria[6].

Through the verification and validation of the ARTS module, it was demonstrated that ARTS code can realistically simulate the plant behaviors during transient and malfunctions. And the ARTS can be applied to the power plant training system to provide information for a regulation judgement. In addition, the models and methodologies developed in this study can be used in the developments of the simulators for other PWR type nuclear power plants.

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