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Performance Enhancement of NSSS T/H Module ARTS for the YGN 1/2 NPP Simulator Using Parameter Estimation

In Yong Seo[a], Do Hyun Hwang[a], Weon Seo Park[b], Jae Seung Suh[c], Gyoo Dong Jeun[d]

[a] *KEPRI, 103-16 Munji-dong, Yuseong-gu, Daejeon, 305-380, Korea*
[b] *KHNP, 514 Kyema, Hongnong, Yonggwang, Jeonnam 513-882, Korea*
[c] *ENESYS, 337-2, Jangdae-dong, Yuseong-gu, Daejeon, 305-308, Korea*
[d] *Hanyang University, 17 Haengdang-dong, Seongdong-gu, Seoul, 133-791, Korea*

1. Introduction

Since nuclear energy was first used to generate electric power, the evaluation of the behavior of nuclear plants in accident scenarios has been an important area of research in the field of nuclear safety. But, as is the case in other engineering fields, the development of experiments to assess this behavior is usually not possible at commercial nuclear power plants. This makes the use of simulation models capable of reproducing the plant behavior necessary. These models are normally validated by developing experiments at test facilities. In this way, the regulatory bodies allow the use of thermo hydraulic simulation codes to guarantee the safe operation of the installations, but only if the uncertainty associated with the simulation is properly quantified [1]. The uncertainties associated with a thermo hydraulic simulation have different origins such as, for example, the limitations of the models used to describe the physical processes that take place inside the plant, the errors associated with the numerical methods used by the codes in the resolution of such models or the unknown values of different variables necessary to build the plant model. In order to quantify and limit these uncertainties, several methodologies have been developed [2]. All of them require a certain amount of sensitivity analyses, which are manually performed, and so they depend strongly on the analyst's judgment.

In this paper, a new approach to mitigating uncertainties caused by user effects in thermo hydraulic simulations is proposed. This consists of using an optimization technique to minimize the user effects introduced in the thermo hydraulic simulations by estimating the optimal value for some of the parameters of the thermo hydraulic model considered. The error function to be minimized is constructed using the values associated with output variables of the model, which are compared to given references derived from plant data [3]. The optimization technique selected is the use of a compensation controller, as it has proven more efficient than alternative methods used to deal with this kind of problem [4]. The rest of the paper is structured as follows, in Section 2, we present the ARTS-YGN code development, used as thermo hydraulic module for YGN 1/2 NPP [5]. In Section 3 we use the optimization technique to estimate initial and boundary conditions for a steam generator water level control model used to simulate an experiment performed at the YGN 1/2 NPP. Finally, in Section 4, the main conclusions of the paper are presented.

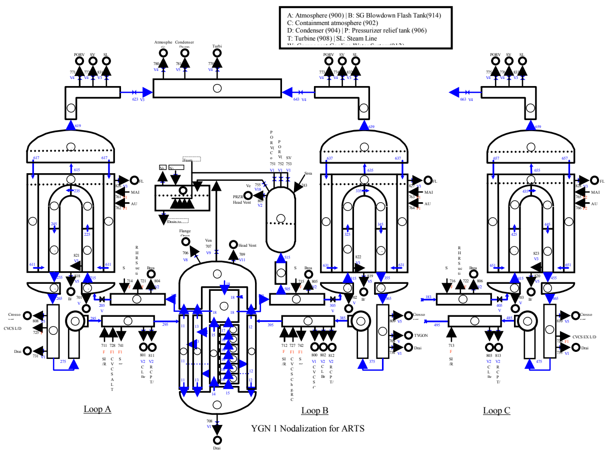

Figure 1. Nodalization for YGN1/2 ARTS

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.

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.

3. SG modeling for the level transients

The use of compensation controller method in the study of the behavior of nuclear plants is widely spread in the nuclear community, since they provide a qualitative understanding of the physical phenomena involved in a given situation such as swell and shrink. This kind of study allows the performance of sensitivity analyses of certain phenomena, and the identification of the most important parameters involved in a rapid and easy way.

4. Conclusion

In this paper a new approach to mitigating the user effects introduced in thermo hydraulic simulations has been proposed based on the use of an optimization technique for thermo hydraulic parameter estimation. This methodology has also been successfully applied in steam generator water level control studies, both of which are of great interest in the field of thermo hydraulics. In one of these studies the methodology is applied to the determination of boundary conditions using a best estimate code commonly used to analyze transients in nuclear power plants, such as RETRAN, and the other study is focused on the estimation of some of the effective parameters of a swell/shrink effect of steam generator water level which can be used in the qualitative evaluation of operational transients.

The methodology proposed is consistent with the methodologies developed for quantifying the uncertainty of thermo hydraulic simulations. It can also be used inside these methodologies to help in the performance of sensitivity analyses. Using the automatic method presented here the uncertainty due to user effects can be minimized.

In this paper the compensation controller method has been selected as the optimization technique to estimate parameters in thermo hydraulic models. This method has been selected as it has turned out to be quite efficient at dealing with this kind of problem. It provides good results for the parameter search and optimization problem without being excessively time consuming. In the application using a best estimate code, the parameter estimation method proposed, has not only obtained the best values for some of the boundary conditions to reproduce the experimental data, but it has also been possible to identify the limitations in models implemented in the ARTS code to reproduce the heat transfer exchange after the dryout. This fact is of especial interest because the measurements in the experimental facilities are focused on determining the limitations of the simulation codes in order to improve their response, and it is extremely important to assure that the plant model is the most appropriate and that it does not affect the calculations performed.

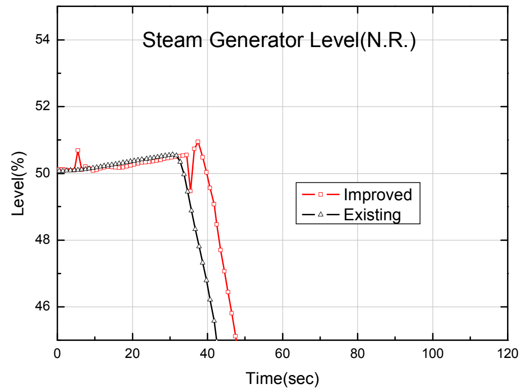

Figure 2. Comparison between the SG level in main steam line break(MSLB 30%) accident at YGN 1/2 Simulator

The results also show that, depending on the transient and on the number of variables considered as reference, the optimum values of the effective parameters considered vary, but that the response for the plant evolution in the situations examined can be considered acceptable [6].

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