Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 24-25, 2024

Development of SUPER Code for Simple Random Sampling Simulation

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1. INTRODUCTION

The SUPER(Specific User Program for Efficient Random sampling simulation) code features powerful random distribution generation capabilities and includes efficient modules for controlling input and output files required for calculations. It also has a Holder module for using executable files as modules. This study introduces the SUPER code, a randomly designed statistical distribution simulation code developed to incorporate various functionalities based on these features.

The SUPER code can be integrated with RELAP or SPACE codes to freely generate simulation inputs using random statistical distributions. The main statistical modules can generate random distributions following Normal, Exponential, Log-Normal, and Uniform distributions. This paper verifies the proper functioning of these features and also introduces the approximate shapes of the statistical distributions.

2. METHODOLOGY

Several programming languages were utilized in this research and development. The integration and control parts were developed using PERL. PERL can create a structure that recognizes executable files and controls them to operate when needed, along with basic regular expressions. The parts for generating inputs and controlling input variations were developed using PASCAL (RADStudio 10.3), and the calculation and distribution of statistical distributions were coded using FORTRAN.

2.1 Sub Modules of SUPER Code

The SUPER code was developed using Visual PASCAL, PERL, and FORTRAN. Input/output for calculations and simulations were generated using PASCAL and FORTRAN programming, while PERL was utilized to control all file system for calculations. Sub modules and some executable files necessary for calculations and simulations can be controlled as modules using PERL's HOLDER function. Through HOLDER, parts developed in PASCAL and FORTRAN can be integrated into PERL to create a single package. This series of processes enables SRS (Simple Random Sampling) simulations.

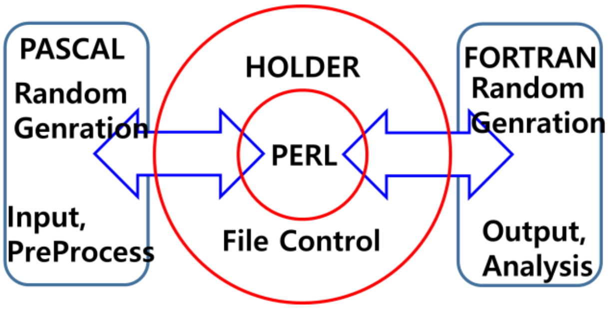

Fig. 1 File control and input/output generation of SUPER Code

2.2 Working Algorithum

In this study, using SUPER code, which automated the procedure in Fig 1, SRS analysis was performed by converting specific variables in input statements simulating 124 pairs of steady states and transient calculation into variables following a random statistical distribution.

The code generally allows for random simulations using the following three distributions. In particular, the Normal distribution and Uniform distribution are examples of random distributions used in current FSAR LOCA analyses. The use of these distributions is based on the theoretical characteristic that the range and nature of errors in the variables used in calculations can naturally depend on their frequency of occurrence, thereby representing the error range due to actual physical phenomena.

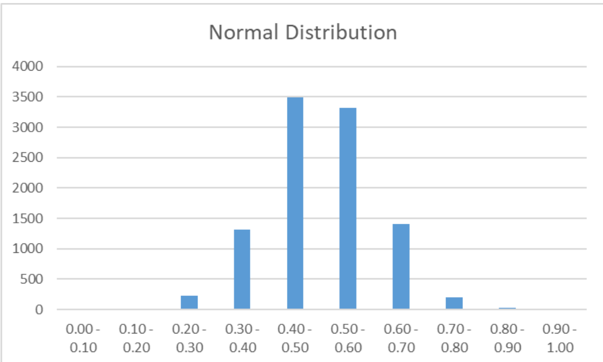

Fig. 2 Normal distribution statistics of SUPER Code

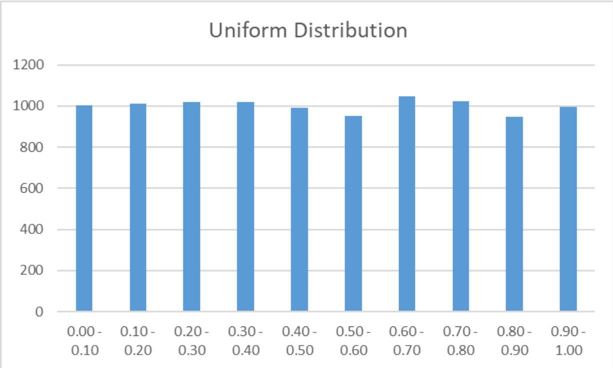

Fig. 3 Uniform distribution statistics of SUPER Code

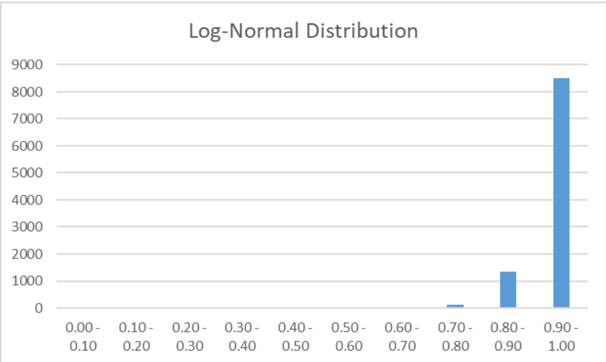

Fig. 4 Log-Normal distribution statistics of SUPER Code

2.3 Simple Random Sampling Simulation of SUPER Code

To perform SRS simulations, the variables to be used in the sensitivity analysis must be selected, and the displacement and distribution characteristics of these variables must be determined. Fortunately, according to the approved content by regulatory agencies, it has been confirmed that up to approximately 30 variables can have an impact. However, in this paper, the focus is on verifying the proper functioning and performance of the code along with its development.

Table 1. Random parameters list

No.	Parameter	Distribution	Mean Fraction	Uncertainty
1	Fq	Uniform	1.0	0.001
3	Fuel conductivity	Normal	1.0	0.001
4	Core Power	Normal	1.0	0.01
5	1-Phase Cd	Normal	1.0	0.02
6	2-Phase Cd	Normal	1.0	0.02
7	Pressurizer pressure, bar	Normal	1.0	0.0001
8	SIT pressure, bar	Uniform	1.0	0.002

Therefore, we will select approximately eight basic variables as random variables and verify whether the functionality to graphically derive SRS output characteristics from actual thermal-hydraulic analysis can be implemented. The random variables and their statistical distribution characteristics used in this study can be summarized by the eight variables listed in Table 1.

3. RESULTS

Using the SUPER code, the primary distributions for SRS analysis in thermal-hydraulic analysis are the Normal distribution and Uniform distribution. Additionally, the log-normal and exponential distributions are typically involved in particle distribution characteristics. Therefore, the SUPER code can be effectively used not only for SRS analysis in thermal-hydraulic analysis but also for containment spray analysis using log-normal and exponential distribution functions.

In particular, these functions can be useful for implementing fission product removal models due to spray droplets in source term impact assessments, such as those conducted with RADTRAD and NAME_LSC codes. This characteristic indicates that the SUPER code can also be integrated with future comprehensive accident impact assessment programs like GOD MASTER.

To perform SRS analysis, it is necessary to create 124 steady-state and transient-state input scripts according to the approved method. These scripts must include variables selected based on random statistical distributions, ensuring that each script contains different random distribution data sets for these variables. Automating the analysis of all generated input scripts is the most efficient approach.

The SUPER code developed in this study fully accommodates these functionalities. It is a powerful tool designed to generate 124 input scripts, execute all processes, output analysis results, and plot graphs, all in one seamless operation.

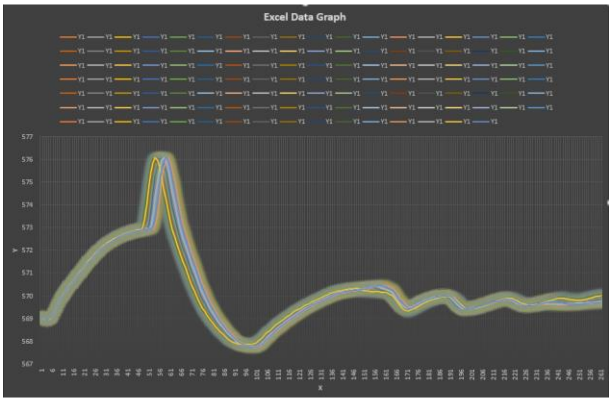

Fig. 5 Cold Leg Temperature SRS graph using GNU plot module under SUPER code(RELAP code output)

To successfully validate the SUPER code, the entire analysis process was automated. Figures 5 through 8 were generated from a single execution, showing results obtained by running the RELAP and SPACE codes. The graph generation functionality produced Excel graphs through an Excel control module and graphs generated by GNU plot. The entire series of processes was performed very successfully, resulting in the completion of the graphs.

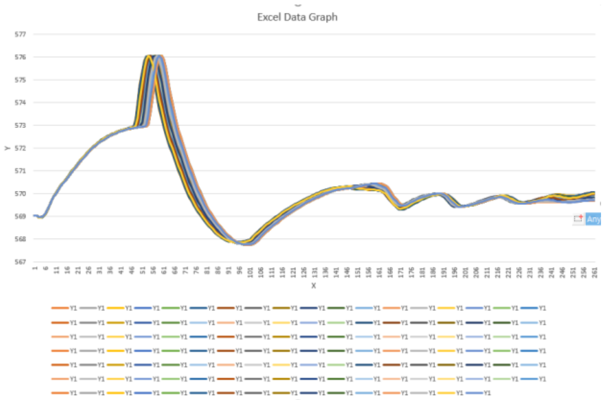

Fig. 6 Cold Leg Temperature SRS graph using Excel control module under SUPER code(RELAP code output)

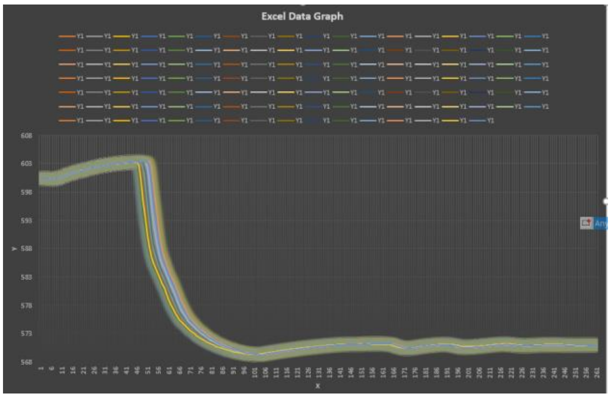

Fig. 7 Peak Cladding Temperature of 124 SRS graph using GNU plot module usder SUPER code (SPACE code output)

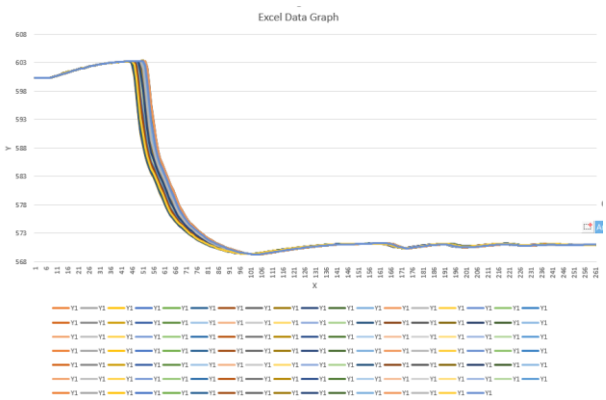

Fig. 8 Peak Cladding Temperature of 124 SRS graph using EXCEL control module usder SUPER code (SPACE code output)

4. CONCLUSIONS

In this study, we developed a comprehensive tool for Simple Random Sampling (SRS) Simulation. All input scripts for SRS analysis were automatically generated, and each script could set different variables following random statistical distributions. When these variations adhere well to statistical distributions, they are expected to be an excellent mechanism for handling uncertainties. In conclusion, the SUPER code is anticipated to be an very efficient tool capable of performing everything from initial input to final analysis results and graph generation in a single run.

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