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Lessons Learned from Wolsong #1 Simulator Upgrade Development to Integrate MAAP4 Module into an Existing Simulator Software

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1. Introduction

After the accident of Fukushima Daiichi, the importance of the severe accident analysis and simulation has been emphasized in many aspects. Almost simulator facilities of nuclear power plants have been used for the operator training under the scope from normal operations to emergency operations without severe accidents. It is known that there are about fifty simulators with the severe accident simulation function in the world. In Korea, there are some simulators that have the severe accident simulation by turn-key development as shown in Table I [1]. For the technology self-reliance in this area, it is necessary to improve domestic skills and knowledge.

Table I. Severe Accident Implementation Status in Korea

Training Center	#1	#2	#3
Kori	O	U	O
ShinKori	-	-	-
Hanul	O	O	-
Hanbit	-	-	-
Wolsong	-	-	U

Therefore, unified software platform and integration methods for several different simulation models are strongly recommended to be developed. This research will be helpful to integrate other physics models such as fire analysis code, seismic code, other severe accident code and etc. In this research, the Wolsong#1 simulator upgrade project has been reviewed with the focus on the severe accident simulation. M4C (MAAP4-CANDU) was used as a basis code since the reactor type of the reference plant is CANDU.

2. Integration of Two Different Codes

Wolsong#1 simulator has been implemented by L3M's ANTHEM (Advanced Thermal-Hydraulic Model) code. It is a non-equilibrium, non-homogeneous, drift flux model [2]. Meanwhile, M4C has models of horizontal CANDU-type fuel channels and CANDU-specific systems such as calandria vessel, reactor vault, RCS (reactor cooling system) and containment systems. So, some systems should be duplicated in each code. For example, the hot leg of RCS can be calculated by ANTHEM code in the normal operation mode and it can also be calculated by M4C code in the severe accident mode. However, it is not necessary to calculate this value two times at all time. In the case of Wolsong#1, an instructor can switch both of them using the calculation mode selection.

2.1 Interface between M4C and Existing models

The basic and simple way to implement the interface between M4C and existing model is the following steps. First, we should identify boundaries of the existing models that are interfaced by the scope of M4C. Second, a virtual interface node should be put at the boundary. This process can be depicted as Figure 1. An interface object has integrated variables from two input sides and one output side and the type of calculation modes.

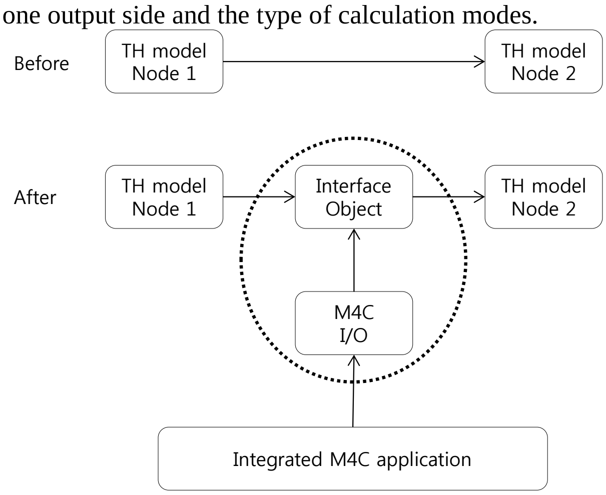

Fig. 1. Position of an interface object between the different type models.

To make an interface object, we should consider that the kind of node type is connected with MAAP4 as follows:
- Homogeneous TH model,
- ANTHEM model including 2-phase,
- Containment and HVAC,
- I&C,
- Valves in the RCS/SG and etc.

According to the connected node type, a different interface object will be implemented and connect to each other.

2.2 Development of Integrated M4C

The stand-alone M4C should be modifies as an integrated M4C. It means that the integrated M4C can be controlled by the FSS (full scope simulator) platform software with a unit time step. To implement this, the M4C source code should be modified to meet some requirements of the software integration. In general, to share information between M4C and the existing simulation software, an interface I/O and additional functions are developed as they can be merged into the original M4C source code. As summarized, there are two kinds of software works to make an integrated M4C. One is data sharing part and another is controllable module by external software. In the case of Wolsong#1, MAAP input, output and switch modules have been implemented. In addition, there is a big difference between the stand-alone and the integrated M4C. The integrated M4C doesn't use the parameter file and input file to run a calculation except for acquiring the stable plant status. This information will be got through the existing simulation software by an initial condition and etc. Fig. 2 shows the conceptual relation between the integrated M4C and the existing simulation platform. In general, the real-time sharing database is provided by a simulator vendor or developer.

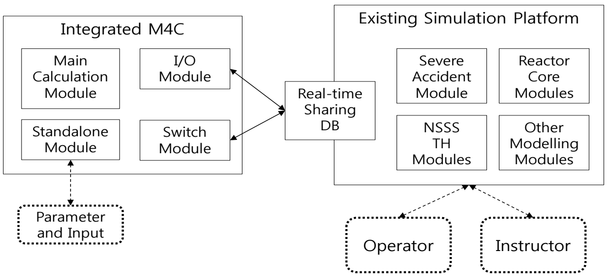

Fig. 2. Conceptual relation between the integrated M4C and existing simulation software.

2.3 Calculation Comparison

The reference graphs are the calculation results of the stand-alone M4C with some designated severe accident scenario such as LBLOCA (Large Break Loss of Coolant Accident), LBLOCA without LOM (Loss of Moderator Cooling) and SBO (Station Black Out) with RCP seal LOCA. In order to compare two kinds of M4C calculation results, we should make a monitored parameter list for every test scenario. Fig. 3 shows the calculation comparison for the PHT (Primary Heat Transport) loop void fraction before tuning the main calculation module of the integrated M4C [3].

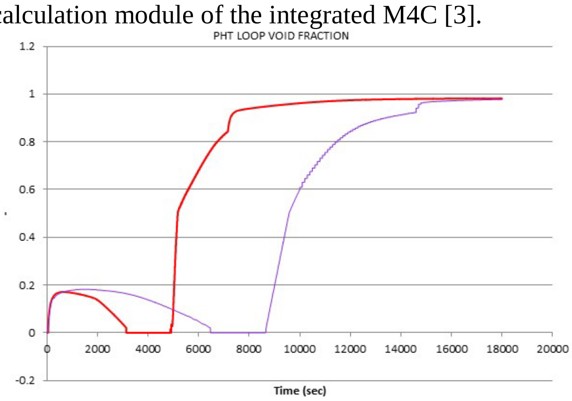

Fig. 3. PHT loop void fraction (red: integrated M4C) before tuning the main calculation module.

Fig. 4 shows the calculation comparison after tuning the integrated M4C [3]. These two figures show the importance of the tuning work for improving the fidelity of calculations as close as ones of the stand-alone M4C.

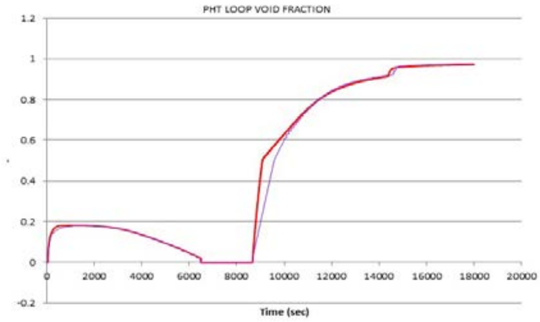

Fig. 4. PHT loop void fraction (red: integrated M4C) after tuning the main calculation module.

2.4 Overall Process of MAAP5 Integration

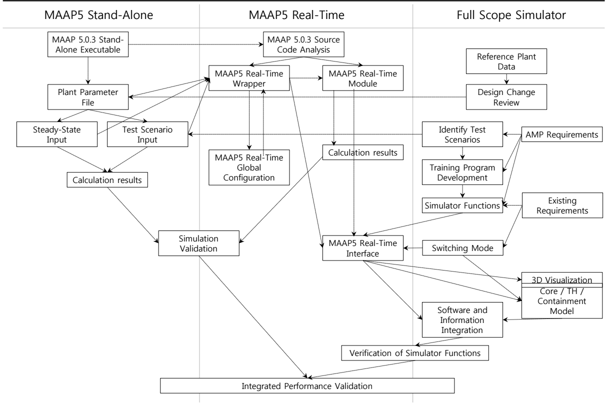

Fig. 5. Overall process of integrating MAAP5 into existing FSS simulator

Fig. 5 shows how to modify the MAAP5 stand-alone program to be the real-time integrated format on account of various requirements. It includes a development process and also a verification and validation process.

3. Conclusions

Integration techniques for several different simulation codes can be useful to expand the scope of the existing simulation. As the public has more interests on the safety of the nuclear power plant, the integration techniques are getting more important. Considering of current situations, unified software platform can be a basis of digital twin simulators, synchronized simulator with real power plant, virtual reality simulator and etc.

REFERENCES

[1] S. Lee, "Training Report of Wolsong#1 Simulator Development", 2018.

[2] www.mapps.l3t.com/advanced-steam-supply-system-model.html

[3] G. Benoit et al, "Acceptance Test Result of Severe Accident for Wolsong#1 Simulator", 2018.