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Development of PCS Simulation Engine for HANARO Simulator by Using MARS 3.1

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1. Introduction

KAERI has started to develop a HANARO (High-flux Advanced Neutron Application ReactOr) research reactor simulator based on the best-estimate code MARS 3.1 (hereafter called as MARS) for operating staff training. In previous research [1], we developed the NSSS calculation engine for SMART simulator based on MARS and the simulator environment of Jade 4.0 developed by GSE [2]. For the development of the HANARO simulator, however, the simulator environment has been changed to 3KeyMaster [3], so that we also developed a real-time thermal-hydraulic calculation engine, 'RTEXMARS' which is interfaced with 3KeyMaster by using MARS.

2. Development of HANARO PCS Model

Development of HANARO primary cooling system (PCS) model is divided into four parts: 1) Development of MARS input deck for PCS of HANARO including the reactor pool, 2) Development of the global interface variables with 3KeyMaster, 3) Development of interactive control function for communication with 3KeyMaster to update boundary conditions and 4) Development of additional function of point kinetics to simulate the rod control, reactivity depletion by fuel burn-up and xenon transient.

2.1 MARS Input for HANARO PCS

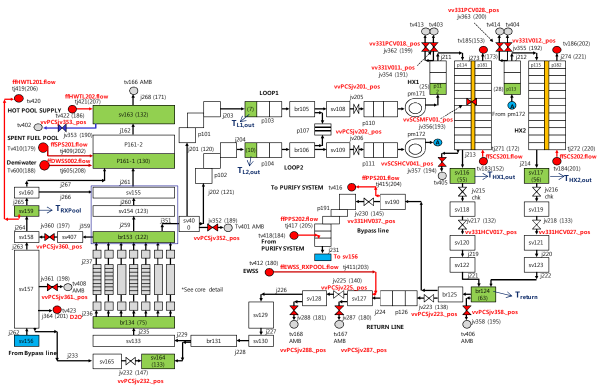

Fig. 1 MARS model for HANARO PCS

Fig. 1 shows the MARS nodalization of HANARO PCS model. It consists of reactor vessel, two heat exchangers, two primary cooling pumps and reactor pool which is open pool type connected to atmosphere. It is noted that the secondary side of heat exchanger is also simulated in the MARS model.

All boundary conditions are defined by the time-dependent volumes and junctions. Among them, the red colours in above figure are the boundaries which are interfaced with 3KeyMaster. Also, all the valves except for the check valves are controlled by 3KeyMaster. For this purpose, a normalized valve area is always updated with the value determined by control logics from 3KeyMaster.

For the simulation of reactor regulating system (RRS), integrated control rod worth versus rod inserted length was implemented into the input deck. Rod insertion length will be determined by the RRS control logics.

2.2 Global Interface Variables

The HANARO PCS model, called as 'RTEXMARS', is one of the independent modules which are supervised by a master program of 3KeyMaster. Therefore, RTEXMARS should communicate with other modules of 3KeyMaster through common global variables. For this purpose, additional global variables were defined in the RTEXMARS module and 3KeyMaster, respectively. These variables are equivalent to the original MARS global variables and, updated and transferred to the other 3KeyMaster modules every step.

2.3 Communication Functions

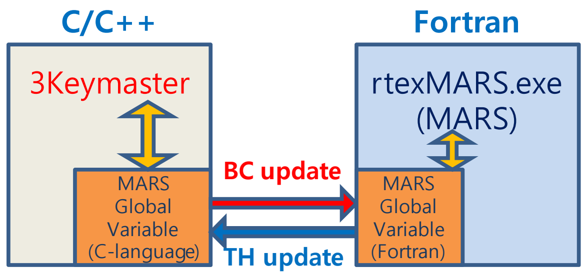

Fig. 2 Communication between MARS and 3KeyMaster

The communication functions of RTEXMARS are required to simulate the reactor power regulation by the rod control, control of valves, and change of boundary conditions such as the pressure, enthalpy and mass flow rate. The MARS code already had such an interactive function for the interface with ViSA [4]. Using this feature, it was able to replace the boundary flow, normalized valve area and various signals with the values from 3KeyMaster. The interactive function for

ViSA, however, is restricted to the control of time-dependent flow rate, valve area, general table and trip. For the remaining controls such as a boundary pressure, enthalpy and reactor regulation controlled by control variables of MARS, additional interface functions were developed to complete the communication with 3Key-Master. The general concept of communication between RTEXMARS and 3KeyMaster is shown in Fig. 2.

2.4 New Functions for Point Kinetics

There is a point kinetics model in MARS for the computation of the reactor power. It is the simplest and cost-effective model based on the approximation that power can be separated into space and time functions. It also computes the fission power and decay power, respectively.

Reactivity feedback model for point kinetics consists of scram reactivity from the table or control variables, feedback reactivity from moderator and fuel temperature, and bias reactivity that is required to set the initial feedback reactivity to zero. Therefore, most of events caused by reactivity change due to control rod moving, feedback from moderator and fuel temperatures can be simulated. Because MARS has no xenon poison model, however, a simple xenon transient model has been developed using the midpoint method.

In addition, for simulation of fuel depletion, a simple depletion model was also implemented into MARS. It is modelled as the RRS control logics withdraw the control rods at the rate of 1 cm/day approximately by inserting appropriate negative reactivity.

3. Initialization and Test

RTEXMARS can be initialized with two methods. One is initialization from the restart plot file generated by stand-alone MARS execution. The other method is initialization using the snapshot of 3KeyMaster, which is called as the IC (Initial condition) file. The former method is required only at the initialization for the first time because stand-alone MARS can't make the IC file of 3KeyMaster. Once it is initialized successfully, however, there is no need to use restart plot file any longer because it is able to make the snapshot file including all variables of RTEXMARS in the simulator environment. If a snapshot file exists, it can be easily done to replace all variables of RTEXMARS with the IC values from snap file.

The balance of plant (BOP) and control/protection logics were modeled using the developing tools provided by 3KeyMaster. Finally, RTEXMARS was integrated with the BOP and control/protection logics, and various tests have been performed to confirm the accuracy, real-time calculation capability, robustness and fidelity. Fig. 3 shows an example of a snapshot during small break at the reactor inlet pipe.

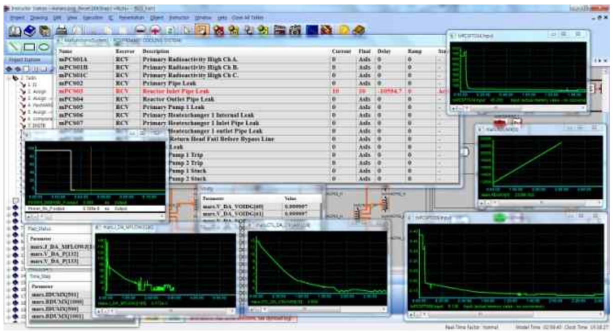

Fig. 3 Snapshot of HANARO simulator during SB-LOCA

4. Conclusions

For the purpose of training HANARO operators, we developed a real-time thermal-hydraulic calculation engine, RTEXMARS based on best-estimate code, MARS and it was successfully integrated with full scope simulation platform, 3KeyMaster. Also, RTEXMARS with minor modifications will be used as a PCS calculation module of Jordan research reactor simulator which will have almost the same configuration as HANARO simulator.

REFERENCES

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