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CRA Control Logic Realization for MARS 1-D/MASTER coupled Code System

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1. Introduction

Both Multi-dimensional Analysis Reactor Safety (MARS) code and Multi-purpose Analyzer for Static and Transient Effects of Reactors (MASTER) code, developed by Korea Atomic Energy Research Institute (KAERI), can be coupled for various simulations of nuclear reactor system. In the MARS 1-D/MASTER coupled code system, MARS is used for the thermal hydraulic calculations and MASTER is used for reactor core calculations. In case of using this coupled code system, the movements of control rod assembly (CRA) are controlled by MASTER. MASTER, however, has a CRA control function which is inputted by user as a form of time dependent table. When simulations related to sequential CRA insertion or withdrawal which are not ejection or drop are performed, this CRA control function is not sufficient to demonstrate the process of CRA movements. Therefore an alternative way is proposed for realization of CRA control logic in MASTER.

2. Method for Realization

2.1 Overall Code Structure

MARS is applicable to the thermal hydraulic analysis of nuclear reactor system [1]-[2]. And MASTER, based on two group neutron diffusion theory, is applicable to reactor core analysis of pressurized water reactor or boiling water reactor [3]-[4]. **Fig. 1.** shows coupling scheme between MARS and MASTER.

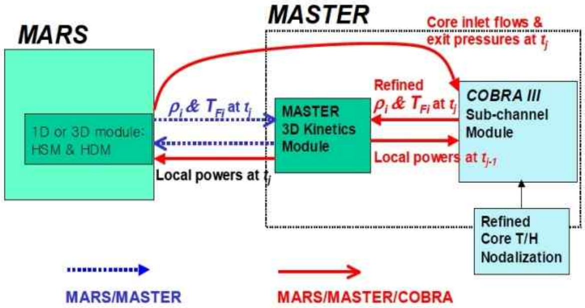

Fig. 1. MARS/MASTER Coupling Scheme

In the MARS 1-D/MASTER coupled system, reactor coolant density and fuel temperature distributions are determined at each calculated time step by MARS and transferred to MASTER. The power distribution is sent back to MARS for the thermal hydraulic calculations at next time step [5]-[6].

2.2 Assumption of CRA Control Logic Realization

To determine the points of CRA movement, U values are used. The U values are manually calculated by the equation below.

$$U = \frac{\Delta T}{C_1} + \frac{\Delta N}{C_2}$$

where, $\triangle T$ is the difference between calculated average coolant temperature by the code and reference average coolant temperature, $\triangle N$ is the difference between calculated reactor power by the code and reference reactor power, C_1 and C_2 are dead band constants of average coolant temperature difference and reactor power difference respectively. According to the calculated U value the CRA movement direction can be decided. If the manually calculated U value by the equation is greater than 1.0, the CRA should be inserted at this point. And if the manually calculated U value by the equation is less than -1.0, the CRA should be inserted at this point.

3. Simulation and Results

In order to verify the feasibility of this control logic, the simulation of reactor power decrease case was performed. When an abnormal trip of normally operated single feed water pump occurs, the feed water flow rate is decreased. To prevent the power mismatch between reactor and turbine, CRA should be inserted. Then additional withdrawal or insertion of CRA is accompanied for the stability of heat balance between primary system and secondary system.

Fig. 2. shows the manually calculated U values by the proposed CRA control logic. Because of the U value

was less than -1.0 at 75 sec, it meant that the CRA could be withdrawal at this point. Thus the CRA withdrawal point could be inputted to MASTER additionally at this point. In this way, the proper CRA movement points will be decided by iterations.

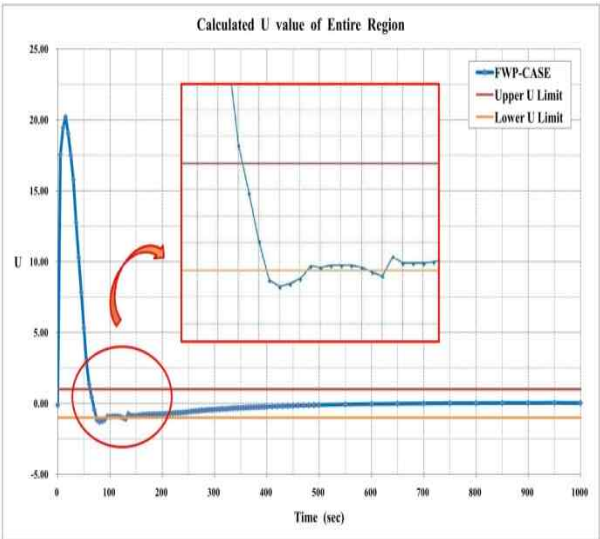

Fig. 2. Calculated U values by Manually Realized Logic

Fig. 3. shows the variation of CRA position by manually realized control logic.

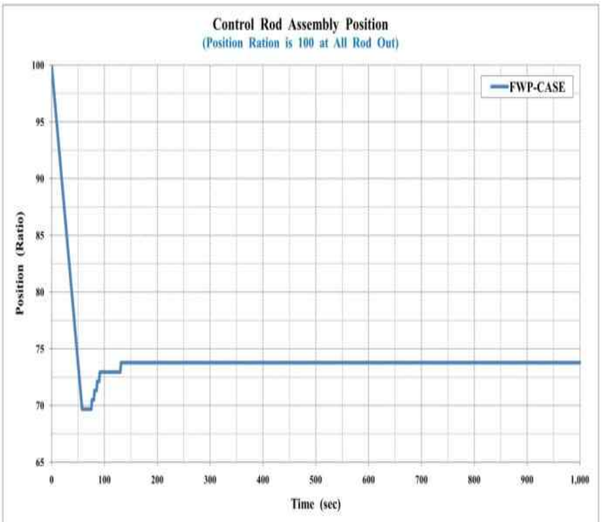

Fig. 3. Variation of Control Rod Assembly Position

Due to the abnormal trip of single feed water pump the CRA was inserted from 0 sec to 58 sec. After the end of insertion the CRA was additionally withdrawn for the stability of heat balance between primary system and secondary system. At the end of the CRA movement the reactor power difference and average coolant temperature difference were not out of the range of their dead bands. Therefore it is confirmed that the CRA is properly inserted or withdrawn by the proposed CRA control logic.

4. Conclusion

In this study, the manually realized CRA control logic was applied by inputting the time dependent CRA positions into MASTER. And the points of CRA movements were decided by iterations. At the end of CRA movement, the reactor power difference and the average coolant temperature difference were not out of the range of their dead bands. Therefore it means that this manually realized CRA control logic works appropriately in the dead bands of the logic. Therefore the proper CRA movement points could be decided by using this manually realized CRA control logic. Based on these results, it is verified that the proper CRA movement points can be chosen by using the proposed CRA control logic in this article. In conclusion, it is expected that this proposed CRA control logic in MASTER can be used to properly demonstrate the process related to CRA sequential movements in the MARS 1-D/MASTER coupled code system.

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