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MARS-DLL Model Development for the JRTR Simulator Application by using the MARS Interactive Controls Capability

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1. Introduction

The plant simulator is an important application instrument that whole nuclear power plant operation situations are conducted with a reality. The power plant situations include normal operation, non-accidental transient, and even break accident conditions. For the training purpose of the plant operators, the simulator facility is installed in a real-sized main control room, MCR. Actually, every nuclear site in Korea has the simulator within their vicinity. KAERI has recently launched a project to develop a simulator of HANARO. It is almost done and a site acceptance test has been performed. As a next, a simulator development project of Jordan Research and Training Reactor (JRTR) has been started. As a short term purpose, the JRTR simulator will be used for the direct test benchmark of fuel rod controller. The simulator consists of 3KeyMatser simulator engine and MARS-DLL[1] for the primary thermal hydraulics. The core inlet and outlet states and related thermal behaviors of primary system are calculated by MARS-DLL and linked to the 3KM variables.

2. Model Development

2.1 General Modification

The JRTR is a 5MW downward open type pool cooling reactor. 18 plate type fuel assemblies are used in the core. There are 21 fuel plates in a fuel assembly. One channel between fuel plates is 2.45 x 66.6 mm dimension. The dimension of plate fuel itself is 1.27x62.1x640 mm. there are 4 individual control rods and 2 SSR in the core. The normal operation condition parameters are listed in table 1.

Table 1. Normal full power operation condition

Parameter	Conditions
power	5.0 MW
flow rate	182 kg/s
coolant temperature	37 ^{o}C
core outlet temperature	44 ^{o}C
pool level	10 m

The MARS nodalization of JRTR consists of the core and the pool cooling system only. Other systems like pool water management system, hot water layer system, heavy water system, and emergency water supply system are modeled by 3KeyMaster components.

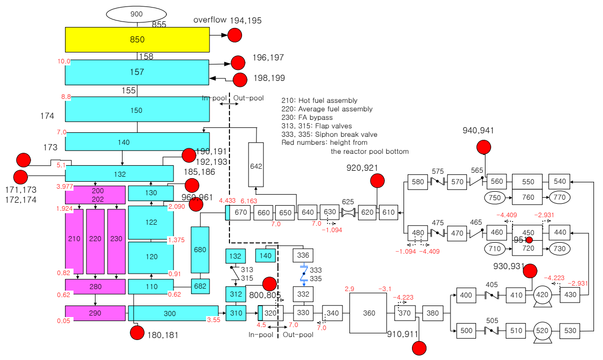

Fig. 1. MARS-DLL nodalization of JRTR

In the JRTR model, major difference from the ordinary nuclear plant is pool system. The coolant flow in and out of pool is important feature as simulating the research reactor. The pool model has the hot water layer volume which is kept in 42 ^{o}C level. The connections from the coolant pool are treated as the time dependent junction which flow rates are linked to 3KeyMaster variables.

2.2 Break Simulation

For the accidental transients, several break points are installed at the desirable position. There are 6 postulated break positions are assumed. The break positions are listed in table 2. All breaks are conducted with servo valves of which area is comes from the MARS-DLL interactive feature. It means user input control.

Table 2. Postulated break positions

valve	position	level*
911	merge line before pump	-4.223
921	merge line after chk	-1.094
931	divide line before pump	-4.223
941	divide line before chk	-2.931
951	HX inside	tube rupture
961	beam line	2.09

*: pool bottom=0.0

2.3 Pump Simulation

For the pump related operation and events, the pump trip and rocked rotor trip are individually assigned for 2 pumps. The rocked rotor trip is the MARS-DLL interactive feature.

2.4 Fuel Rod Simulation

The fuel rod control is another important item in simulator. The simulator gives the fuel rod position variable to MARS-DLL. Then, the reactor power is calculated in the MARS-DLL point kinetics module by using the tabulated position vs. reactivity relationships. MARS-DLL assigns 4 control variables for all control rod reactivity. MARS-DLL can accept the reactivity in a control variable form by using the reactivity feedback input card, 300000NN (NN=11 to 20)[2].

3. Results

For the full capability simulator, the 3KeyMaster components for the pool connected systems should be merged. The internal trip related measure and signal treatments are also modeled and merged into the 3KeyMaster simulator engine. For the individual pre-test of the MARS-DLL, it is linked to ViSA program. The ViSA program provides the interactive bench-marking platform through the real-time interactive capability. For the test, the break junction 911 is abruptly open and the resulting transient is observed. Right after the break occurs, coolant flows out from the loop to ambient without any resistances. The pool level decreases down to 5.1 m. At this elevation, the pool is divided into reactor pool and service pool. Then only the reactor pool coolant flow out until the elevation is 4.38 m, the reactor vessel open entrance elevation. The core cooling is performed by the natural circulation by opening the flip valve. The natural circulation flow begins at 779 second after break and the amount is about 2.2 kg/s with high fluctuation. During the natural circulation period, the reactor pool level is maintained around 4.5 m level.

Reactor trip occurs at 1.012 second after break due to the low coolant flow rate trip of which set point is 144.8 kg/s. In this test run, the reactor power after the break is calculated by the given scram table, not from the interactive control variables.

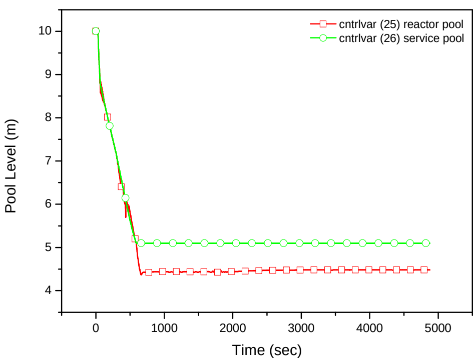

Fig. 2. The Reactor and service pool level

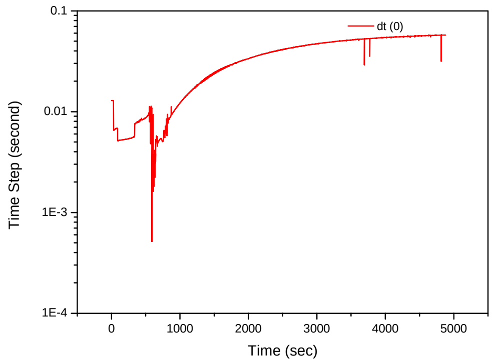

Fig. 3. The calculation time step

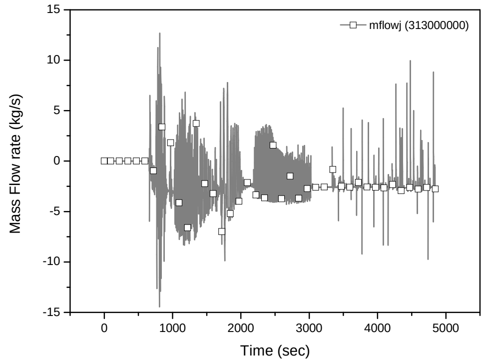

Fig. 4. The coolant flow rate of flip valve

For the simulator application of MARS-DLL, most important parameter is calculation time step and speed. In order to meet the real-time requirement, the time step size should be larger than the calculation speed. At the instance of beginning the natural circulation, time step size decreases down to $5x10^{-4}$ level. But shortly after, the time step size recovers to the sound $5x10^{-3}$ level.

4. Conclusions

A MARS-DLL and its input for the JRTR simulator application are developed. With the aid of ViSA program, the individual test run is performed. The time step size is checked for the major break event. The research reactor cooling capability is kept by the natural circulation flow through the flip valve. The 3Key Master components for the pool connected system and operation signal handling are now under construction. The MARS-DLL has the capability for the simulator application.

REFERENCES

[1] K.D.Kim, *et. al.*, “A visual environment for system analysis codes,” *Progress in Nuclear Energy*, **39**, 3, pp.335-344, 2001

[2] KAERI/TR-2811/2004 MARS CODE MANUAL Volume II: Input requirements, 2007.