Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Application Results of MAAP 5.0.2 to Domestic APR1400 Nuclear Power Plant

Mi Ro Seo*, Hyeong Taek Kim
KHNP-CRI, Nuclear Safety Laboratory, 70, 1312-gil, Yusung-Daero, Yusung-Gu, Daejeon, 305-343, Korea
**Corresponding author: mrseo@khnp.co.kr*

1. Introduction

After the Fukushima accident, EPRI has developed the MAAP (Modular Accident Analysis Program) version 5 that is expected to make up the limitation of MAAP4 and the newest version of MAAP5.0.2 (Build 5020000) was released officially in December, 2013. In this version of MAAP, there are so many changes in the models such as the Lower head plenum model, Debris Coolability model, Molten Core Concrete Interaction, and the analysis scope is enlarged to the phenomena in the spent fuel pool and the half-loop operation.

As a kind of post-Fukushima measures, KHNP is developing the probabilistic safety assessment (PSA) and severe accident management guideline (SAMG) for low power and shutdown (LPSD) mode and MAAP 5.0.2 should be used in these projects as a major analysis program. So, first of all, it is necessary that the parameter file for domestic NPP should be upgraded as current Ver. MAAP4 to Ver. MAAP 5.0.2.

KHNP developed the draft version of parameter file for APR1400 type NPP and is being tested for some basic severe accident sequence. In this study, we try to share the information for newly developed parameter and compare the analysis results using MAAP 5.0.2 with previous results using MAAP4.

2. Methods and Results

2.1 MAAP code

From now on, MAAP4 code has been used to assess the safety of NPP in the plant specific PSA and develop the SAMG in Korea. It is generally agreed that the MAAP4 code is enough to assess and expect the progression of severe accident before Fukushima accident. But, after that accident, there were so many requests that the capability of MAAP is needed to be enlarged. The newest MAAP5.0.2 is enlarged its capabilities to the analysis of phenomena in SFP and the accident progression in LPSD operation mode. The RCS model is expanded from 13 nodes in MAAP4 to 49 water nodes and 29 flow nodes. Also, the containment model is expanded from 39 compartments up to 199 compartments. In addition, the momentum equation is partly introduced in some sub models and there are so many changes in the models of MAAP5.0.2. So, it is necessary to develop the new parameter files for domestic NPP. After that, it is essential to compare the results of major phenomena using MAAP5.0.2 with those using the previous version.

2.2 Parameter File Development

The parameter file in MAAP code is constituted of the model parameter section (Control & Specific Features section) and plant specific parameter section (Core, Primary system, ESF, Containment /Aux. Building section). In Table 1, the number of parameters for MAAP5.0.2 is compared with that of MAAP4. And we know that the number of parameter is increased for detailed analysis in MAAP5.0.2.[1]

Table 1. Comparison of MAAP Parameter

Section	MAAP5	MAAP4
Control	714	451
Specific Features (MAAP5 only)	1311	0
Core	605	274
Primary system	591	294
ESF	606	509
Containment /Aux. Building	6386	4573
Total	10213	6101

The parameter values in the model parameter sections are mainly used the default value recommended by the code developer, FAI. However, the parameter values in the plant specific parameter sections should be calculated based on the design documents such as the Final Safety Analysis Report.

KHNP developed the new MAAP5.0.2 parameter file (draft version) for APR1400 type plant and tested the steady state case for its appropriateness.

2.3 Steady State Test Run

In the previous MAAP4, before the actual analysis begins, some test cases performed to confirm the mass and energy balance as below[2];

1) Primary system and containment mass error < 0.01%
2) Primary system and containment energy error < 1% - 2%
3) Core energy balance
4) Fission product masses: (Balance 1) – (Balance 2) < 0.1%
5) FP balances should equal the initial values (except Te2 which is converted to TeO2)

If these conditions are met, we can judge that this parameter file is appropriate for the actual analysis.

However, in the MAAP5.0.2, The steady state condition should be achieved using the newly developed parameter file and steady state input given in the distribution package. Therefore, we try to test run using the newly developed APR1400 parameter file and the results are shown below.

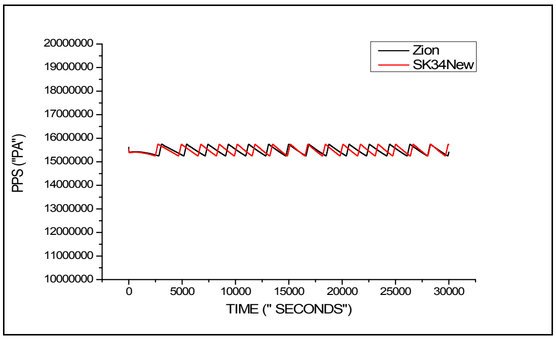

Fig 1. Primary System Pressure in Steady Condition

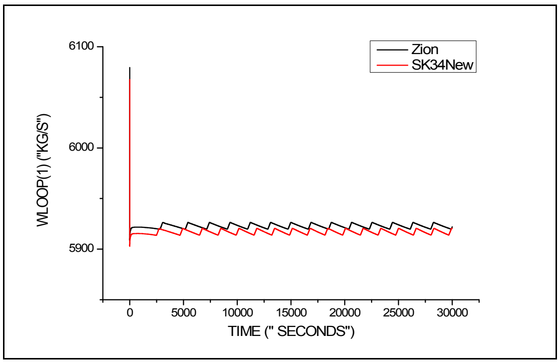

Fig 2. Loop1 Flow Rate in Steady Condition

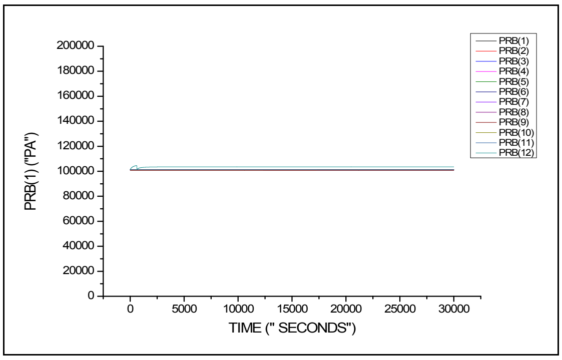

Fig 3. Containment Pressure in Steady Condition

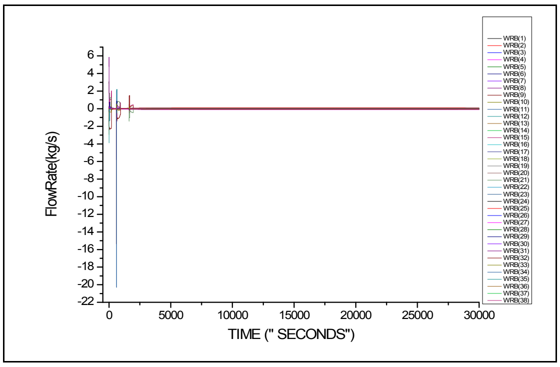

Fig4. Junction flows in Steady Condition

As shown in this figure, we can conclude that the steady-state condition for primary systems has been achieved and the result can be acceptable. However, for the containment, we need to check the phantom flows (artificial flows) through the junctions because the fluctuations have happened shown in Fig. 4. So, we ask to FAI for this problem, and we can get the answer that this fluctuation can be negligible and newly developed parameter for APR1400 is appropriate to analysis the actual cases.

2.4 Accident Scenario

To compare the results of MAAP5.0.2 with those of MAAP4, we select the two accident scenarios. The first case is the Large LOCA sequence initiated by the Double Ended Guillotine Break in cold leg with that all safety injections including Aux. Feedwater system are not available except Safety injection Tank. Case L-4 is performed by MAAP4.0.7 and Case L-5 is performed by MAAP5.0.2. The second case is the SBO sequence initiated by the Loss of AC and DC Power with that all safety injections including Aux. Feedwater system are not available except Safety injection Tank. Case S-4 is performed by MAAP4.0.7 and Case S-5 is performed by MAAP5.0.2. The analyses are performed for 72 hours as a MAAP time step.

2.5 Analysis Results

The representative major event occurrence time for each case are summarized in Table 2.

Table 4. Major Accident Progression

Case	Core Uncover (S)	RV Fail (S)	CV Fail (S)	Eroded Depth (M)
L-4	11.25	9081.81	NO Fail	4.12
L-5	2.49	8690.18	NO Fail	0.894
S-4	6923.65	13547.38	NO Fail	3.43
S-5	7699.33	21596.69	NO Fail	0.894

And the changes of the major parameters, such as primary system pressure and containment pressure, are shown in next figures.

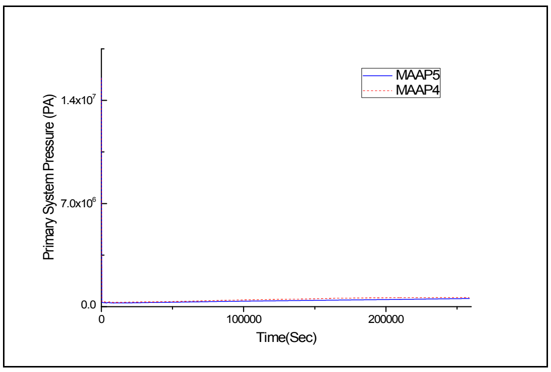

Fig5. Primary System Pressure Change Comparison in LLOCA sequence

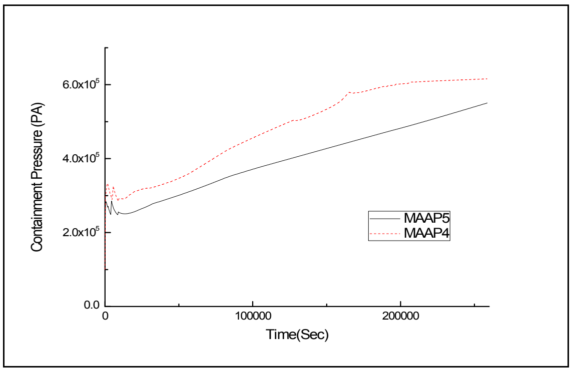

Fig 6. Containment pressure Change Comparison in LLOCA sequence

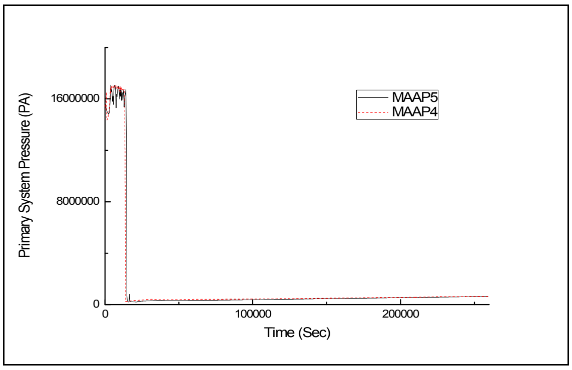

Fig 7. Primary System Pressure Change Comparison in SBO sequence

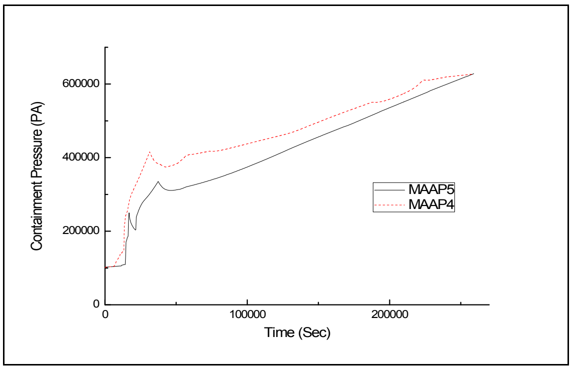

Fig 8. Containment pressure Change Comparison in SBO sequence

As shown in above figures, it can be judged that the major phenomena are well predicted by newly developed parameter file for APR1400 severe accident scenarios.

However, the changes of concrete eroded depth, which is related with the new MCCI model in MAAP5.0.2, are so much different as shown in Fig 9 and Fig 10. It is thought that it may be happened due to the melt eruption model applied to MAAP5.0.2. The concrete liquidus-solidus temperature profile in newly developed parameter file is set to the values of the limestone common sand recommended as a default values. So, it is necessary that the analysis for MCCI should be performed once again after we change the parameters for the concrete section as the values for specific values of the domestic APR1400

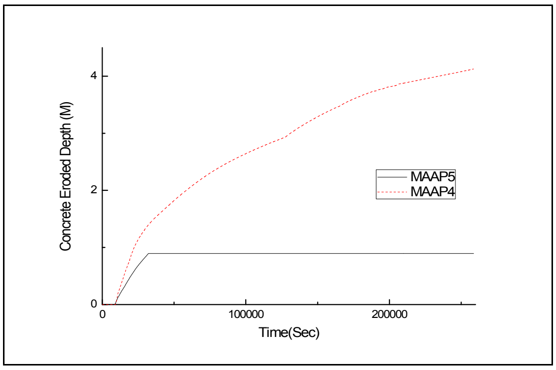

Fig9. Concrete eroded depth Comparison in LLOCA sequence

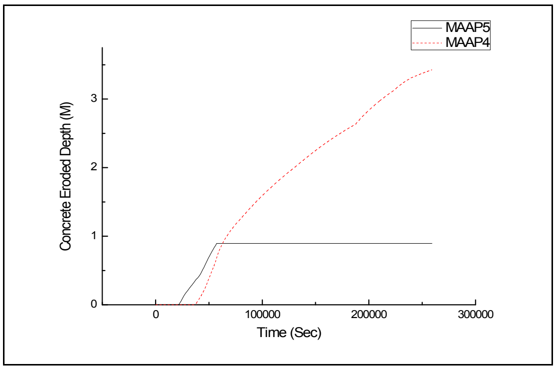

Fig 10. Concrete eroded depth Comparison in SBO sequence

3. Conclusions

Currently, while developing the LPSD PSA and LPSD SAMG as a kind of post-Fukushima measures, KHNP have the plan in order to upgrade the old parameter file based on MAAP4 to that based on MAAP5.0.2 for all domestic nuclear power plants.

As the first effort, we developed the MAAP 5.0.2 parameter file for APR1400 type NPP. In this study, we can find that the newly developed MAAP5.0.2 parameter file for domestic APR1400 type is appropriate for actual analysis. But, as a draft version, it is judged that it should be revised through the sensitivity studies, especially focused on the newly introduced models in MAAP 5.0.2.

REFERENCES

[1] Mi Ro Seo, "Current MAAP Development Status and Application plan in Korea", MELCOR/MAAP Workshop, December, 2013

[2] MAAP Advanced Training Manual, FAI, May 2013