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Consideration of MAAP 5.0.2 ESF Model Characteristics for APR1400 NPP

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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, that is to say, the appropriateness of the model for the severe accident phenomena and the applicability to the phenomena in the spent fuel pool and the half-loop operation. Up to now, the newest version of MAAP is 5.0.2 (Build 5020000) that was released officially in December, 2013. In addition to this, it is expected that MAAP 5.0.3 version will be published sooner or later.

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 has developed the draft version of parameter file for APR1400 type NPP and is being upgraded continuously.

The Engineering Safety Features (ESF) model is one of the unique features of MAAP. In this study, we try to share the general information of the MAAP ESF model and the specific characteristics of APR1400 ESF model based on the newly developed MAAP 5.0.2 parameter file.

2. Methods and Results

2.1 MAAP ESF Model

Before Fukushima accident, it is generally agreed that the MAAP4 code is enough to assess and expect the progression of severe accident, and so MAAP4 code has been used in the plant specific Probabilistic Safety Assessment (PSA) and Severe Accident Mitigation Guidance (SAMG) development in Korea. But, after that accident, there were so many requests that the capability of MAAP is needed to be enlarged especially to the analysis of phenomena in SFP and the accident progression in LPSD operation mode. In addition to these, the accuracy and appropriateness of parameter value is required in order to reduce the uncertainty of the analysis result.

MAAP code is consisted of so many sub modules that control the phenomena and the plant configurations. And, the related plant specific information should be recorded in the plant parameter file.

The ESF model that is one of the unique features of MAAP is consisted of 2 different models, the Specific Engineered Safeguards systems and the Generalized Safeguards systems. The user has the choice of either using the MAAP specific or the MAAP generalized engineered safeguard systems using the parameter NESF. The basic differences of these two systems are the flexibility of pump line up. The specific ESF model has very specific pump lineups and pump curves and may or may not have heat exchangers capabilities depending on the Control parameters IRECIR and IDISCH which specify the 3 different types of ESF system configuration. The generalized ESF model, on the other hand, allows the users the freedom to model the desired pump lineup (e.g., pump suction/discharge locations), several distinct pump head curves for the same system, model NPSH enhancement flows, and optional heat exchangers for the same set of engineered safeguards systems.

2.2 APR1400 ESF Characteristics

The ESF system design of APR1400 type NPP has the different features compared with OPR1000 type NPP(Korean Standard Nuclear Plant). The most important distinction is that there is no low pressure injection system and 4 safety injection pumps cover the all pressure range in APR1400. In OPR1000, the LPSI system is used as the residual heat removal system and is compatible with the containment spray system. So, in APR1400, the separate RHR Pumps exist and these are compatible with containment spray pumps.

The injection point is changed from cold leg in OPR1000 to direct vessel injection (DVI) nozzle in APR1400.

Another major distinction is that the in-containment refueling water storage tank (IRWST) plays the role for sump and external RWST in OPR1000.

2.3 ESF Parameter Development for APR1400

According to the guideline in MAAP parameter file, if the user selects the specific ESF model by setting the value of NESF equal to 0, it is known that only the specific ESF parameter section is used. Up to this time, the ESF system design features of OPR1000 can be modeled sufficiently using the specific ESF model only. So, until now, generalized ESF model has not been used in domestic NPP parameter file development.

However, the ESF design features of APR1400 are different from those of OPR1000. So, at first, we decided to develop the APR1400 MAAP 5.0.2 parameter file using the generalized ESF model.

During the process of developing the generalized ESF model, we can find the misunderstanding for the ESF model of MAAP. In general, we know that when the NESF is equal to zero, only the parameters in the specific ESF section are used, and when the NESF is equal to 1, only the parameters in the generalized ESF section are used. However, actually, these two models are not separated but used together in the manner of supporting the specific ESF model with the generalized ESF model. If the plant have some specific ESF systems that are not described in specific ESF model, the generalized ESF model can be utilized.

In ESF model of APR1400 parameter file, both the specific ESF model and the generalized ESF model were developed together. The ESF systems represented in the specific ESF section of the APR1400 parameter file is ;

1) IRWST (RWST + Sump in OPR1000)
2) SIT
3) Charging System
4) SIP (HPI in OPR1000)
5) RHR Pump (LPI Pump in OPR1000)
6) Containment Spray
7) RHR Heat Removal (LPI RHR Spray and HX)
8) Cavity Water Injection and Flooding System

And in the generalized ESF section, MAAP provided the following 7 independent pump systems ;

1) containment spray system train A (SPA)
2) containment spray system train B (SPB)
3) low pressure injection train #1 (LPI-1)
4) low pressure injection train #2 (LPI-2)
5) high pressure injection (HPI)
6) charging pumps (CHP)
7) containment spray system train C (SPC)

Among these 7 independent pump systems, the following 3 pump systems are developed for APR1400 generalized ESF model ;

1) Containment Spray system Train A
5) High Pressure Injection
6) Charging Pumps

When the NESF=1, in addition to above parameters in Pump systems, Pump characteristics section should be calculated and used with generalized ESF section. In MAAP code, up to 21 distinct pump characteristic sets may be defined. The input setup consists of defining the three main characteristics:

1) The pumping capacity of a pump (flow vs. head) for a normal, alternate, or degraded line-up.
2) Net Positive Suction Head (NPSH) requirements.
3) Heat exchanger attributes if a heat exchanger exits downstream of the pump.

In APR1400 ESF model, 4 Pumps characteristics were defined ;

1) Normal SPA Flow
2) Normal LPI1 Flow (RHR flow)
3) Normal HPI Flow
4) Normal CHP Flow

Among 606 parameters in the ESF Section, 90 parameters were recalculated and changed from those used in MAAP4.0.7.

2.4 Test Accident Scenario

To confirm the appropriateness of the newly developed parameter, especially focused on the ESF model operability, the test accident scenario, Large LOCA, was selected. The accident is assumed to be initiated by the Double Ended Guillotine Break in the cold leg, and SI injections using Safety injection pumps, Safety injection tanks and Containment sprays are available.

2.5 Analysis Results

The test results using MAAP5.0.2 (L-5) were compared with those using MAAP4.0.7 (L-4). The representative major event occurrence time for each case are summarized in Table 1.

Table 1. Major Accident Progression

Case	SIP ON (S)	Spray ON (S)	Core Uncover (S)	RV Fail (S)
L-4	0.296	5.051	11.253	No
L-5	0.058	5.004	2.393	No

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

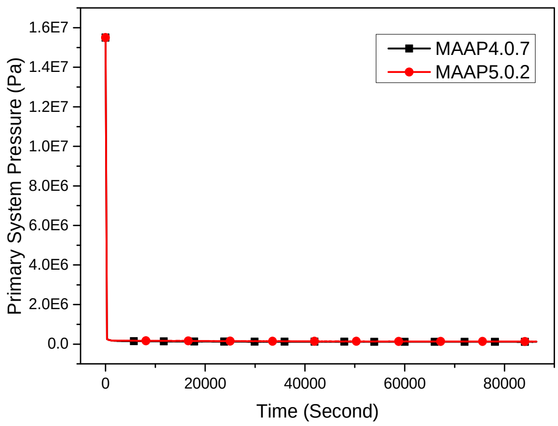

Fig 1. Primary System Pressure Change in LLOCA

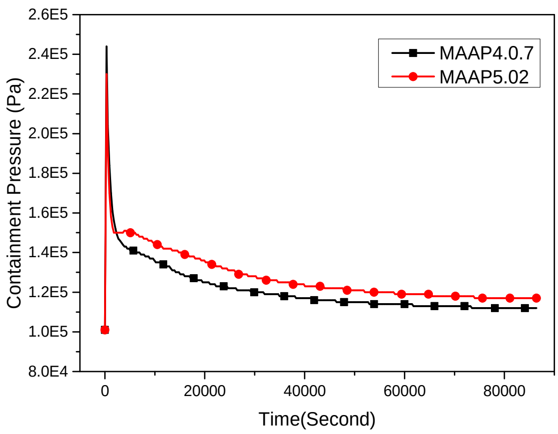

Fig 2. Containment Pressure Change in LLOCA

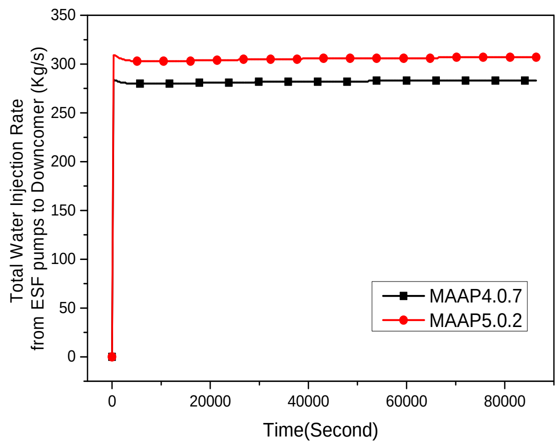

Fig 3. Total Water injection Rate from ESF pump to Downcomer

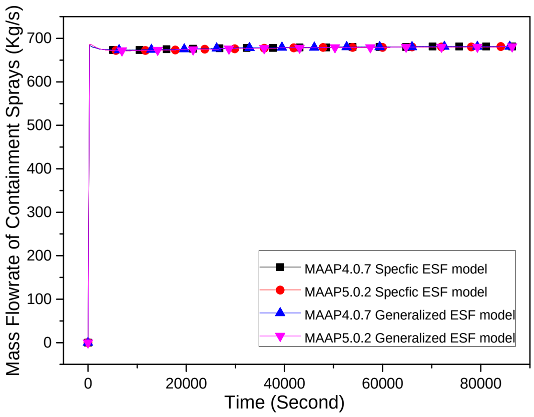

Fig 4. Mass Flowrate of Containment Spray

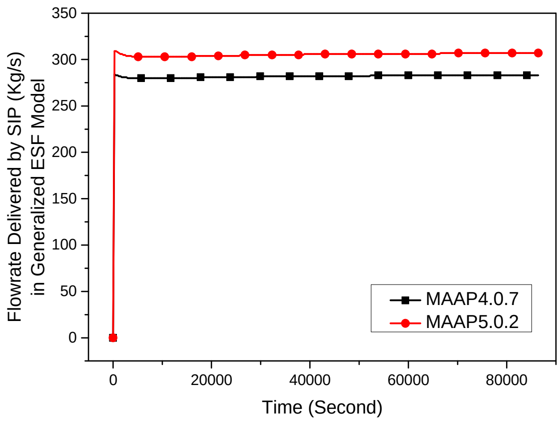

Fig 5. Flowrate Delivered by SIP in Generalized ESF Model

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. Also, the operation of ESF system is shown to be appropriate

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. And, as the first effort, we are developing the MAAP 5.0.2 parameter file for APR1400 type NPP.

In this study, we tried to develop the more accurate and reasonable ESF model of APR1400. In this process, we can find the distinctions and characteristics of specific ESF model and generalized ESF model of MAAP5.0.2. Also, we can eliminate the confusing concepts existed in the two models.

So, it is judged that the newly developed MAAP5.0.2 parameter file for domestic APR1400 type NPP is appropriate enough to analysis the severe accidents during full power operation. However, at this time, we cannot guarantee the appropriateness of this ESF model for the accidents occurred in the low power shutdown mode. So, it should be needed that this newly developed parameter file is continuously revised.

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