Final Functional Test (FFT) of Severe Accident Module in Full Scope Simulators

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1. Introduction

The simulator in Nuclear Power Plant is a facility designed and manufactured to simulate the physical behavior of nuclear power plants and is an essential facility used not only for nuclear power plant reactor operator license tests but also for license refresher training of operators. In 2014, the Nuclear Safety and Security Commission (NSSC) checked the ability to respond to safety management of nuclear facilities and demanded measures to 'strengthen practical training in preparation for severe accidents'. Accordingly, for enhancing accident response capability and improving safety operation of nuclear power plants, KHNP (Korea Hydro & Nuclear Power co.) has been performing gradually reflecting the severe accident functions in the simulators.

This paper intends to connect the severe accident module to nuclear power plant simulators and describe the criteria for selecting scenarios and the result of Final Functional Test (FFT) performance.

2. Methods and Results

Since 2019, KHNP CRI(Central Research Institute) has carried out the task of "Development of Severe Accident Simulation Function to Full scope simulator for Nuclear Power Plant" to implement severe accident functions for eight simulators (Shin-Kori #1~2/#3~4, Hanul #5~6, Shin-hanul#1~2, Hanbit #1~2/#3~4/#5~6, Shin-wolsung #1~2) that do not have severe accident functions.

Simulators were implemented with more accurate environment by receiving the calculation value of the RELAP code, which performs more accurate calculation in the normal state and then when the core exit temperature exceeds 649 degrees, the RELAP code stops and smoothly transfer to the MAAP code.

The Final Functional Test (FFT) was performed after connecting the function-enhanced severe accident module to eight simulators.

The FFT is to perform a simulator function and plant behavior test for long-term operation (normal→ Abnormal→ enter severe accident→ mitigation measures).

2.1. Severe accident module connection

Since the MAAP5 code followed the results of the calculation of the MasterRelap5 and Flowbase reactor building from MasterRelap5Task to the time of the transition to a severe accident Task, the results derived by the two codes are similar at that time. Even if there are variables which some unfamiliar results are derived, soft transfer is possible by applying a method of gradually increasing the weighting Factor of the results of the task of severe accidents through the combination method below.

● Simulator Value = RELAP5 Value x Weighting Factor + MAAP5 Value x (1.0 – Weighting Factor)
when, Weighting Factor = MAX(0.0, MIN(1.0 (1,000 - Maximum Cladding Temperature) / 200))

The result calculated in the severe accident task is transferred to the memory area of the simulator according to the Assign content defined in the .ass files.

2.2. Scenario selection

The FFT was divided into a severe accident prevention test to confirm the maintenance of the performance of the existing simulator and a severe accident mitigation test to confirm whether a severe accident module is implemented normally and whether a severe accident is alleviated by appropriate measures. In addition, some of the ANSI/ANS 3.5-2009[1] related test items were tested to confirm whether the simulator was maintained in normal operation.

In a severe accident prevention test, malfunction and component malfunction are injected each accident situation to set initial conditions, and important alerts and variables are checked after an accident occurs. In addition, accident mitigation measures according to EOP and MOG are carried out to confirm that the nuclear power plant condition reaches each stopped operating condition and remains stable.

The criteria for selecting severe accident prevention scenarios are as follows:

· Refer to the Accident Management Plan (AMP) for multiple failures and natural disasters exceeding design standards.
· Exclude the details of non-analysis of the AMP (ATWS, ISLOCA, LOSFP)
· Exclude accidents that cannot be simulated by simulator

In the severe accident mitigation test, it is checked whether the accident worsens by mistake in accident prevention measure after the accident, and CET increases to exceed 649 degrees as the core is finally exposed. As a subsequent step, it is checked whether each simulator satisfies the conditions for termination of severe accidents through measures to alleviate severe accidents such as alternative spraying of reactor buildings.

The criteria for selecting scenarios in the field of mitigation test are as follows:

· Core Damage Frequency (CDF) high-frequency background (Refer to Severe accident management capability evaluation of Accident Management Plans)
· Case of transferring to a severe accident when analyzing the AMP
· Initial event grouping (SBO, SGTR, LOCA, MSLB etc.)
· Except for cases where reactor vessel is damaged early (ATWS) and cases where AMP are not analyzed (ISLOCA)

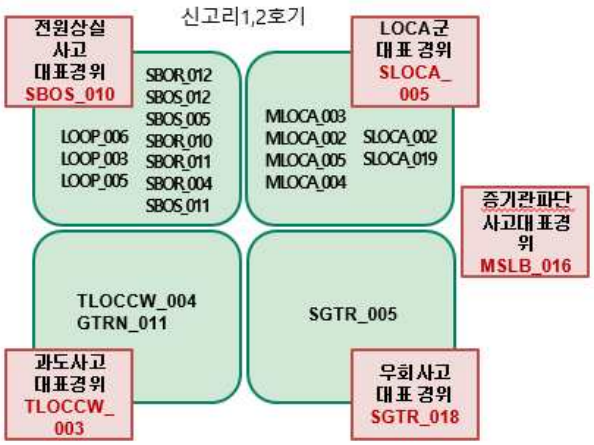

Fig. 1. Sample result of selecting a representative accident case in the field of Severe Accident mitigation

2.3. Final Functional Test execution

The FFT is a final functional test to verify the simulation function of severe accidents for improved simulator and to confirm whether the performance of the existing simulator is maintained, and the test was conducted at the relevant plant training center.

For the FFT, five severe accident prevention procedures and five severe accident mitigation procedures were selected as representative accidents in the AMP, and each of the eight simulators performed the final functional tests, and all eight simulators met the termination conditions.

The conditions for termination of severe accidents considered here are as follows.

Table 1: Scenario termination condition

No.	Item	Termination condition
1	CET temperature	Stable or reduced below 371.1 °C (severe accident termination condition)
2	Pressure of the containment building	Stable or reduced to less than 133.6 cmH2Og (Spray end condition)
3	Hydrogen concentration	Stabilized or reduced to less than 5% (Condition of termination of heavy accident)

3. Conclusions

After installing the function-enhanced severe accident module on eight units, a severe accident prevention procedure and a mitigation procedure were selected from the AMP for the FFT of the severe accident.

No separate defects occurred in the performance of the FFT, and the termination conditions were satisfied in all tests. In the future, we plan to resolve inconsistencies in continuous severe accident functions and supplement functions.

Finally, if the severe accident module is completed, it will be widely used for operator training for severe accidents, which will greatly contribute to the safe operation of the plant.

REFERENCES

[1] ANSI/ANS-3.5-2009, "*Nuclear Power Plant Simulators for Use in Operator Training and Examination,*" *American Nuclear Society, La Grange Park, IL, September 2009*