Severe Accident Module Functional Test in SKN#3,4 Simulator

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1. Introduction

The simulators of nuclear power plants in Korea are mainly used for operator training and operator license testing by simulating the operation characteristics and response of each type of reactor.

As the level of demand for safety operation of the plant increases due to Fukushima follow-up measures, the development of simulators capable of implementing severe accident is continuously required. Accordingly, to contribute to enhancing accident response capability and improving safety operation of the plant, KHNP CRI (Central Research Institute) has been performing gradually reflecting the severe accident function in all the simulators of all sites including Shin-Kori Units 3 and 4.

In this paper, we want to address the results of the first stage functional performance test conducted by linking the severe accident module to the simulator of Shin-Kori Units 3 and 4.

2. Methods and Results

The simulator is a facility that allows operators to simulate the response of the plant under an environment similar to the actual situation, and is essential for the operator's education and license refresher training as well as the reactor control license test. The simulator is manufactured from a reference plant, and the simulated range is equipped to take the same action as the actual plant for event deployment similar to that of the reference plant when the operator is training using the manual. As a requirement of the Nuclear Safety Commission, a simulation function of a severe accident is required to be applied to the entire Nuclear power plant simulator for implementation of the task of strengthening the training against severe accident, and training using various severe accident scenarios a in accordance with follow-up measures to Fukushima. So the KHNP CRI intends to develop and mount the severe accident module to Shin Kori Unit 3&4 simulator through the simulators severe accident function implementation project.

The project is carried out in two steps in total, and in first step, the development environment of the simulator model is analyzed and the connection points with MAAP5(the severe accident code) code are derived to complement the simulator model to confirm the severe accident function in the simulator environment. Second step is to perform final simulator function and behavior test for FFT(final function test : Long term operation(normal → abnormal→ severe accident entry→ relaxation measures applied)) through training exercise scenario according to ANSI/ANS 3.5 guidelines through enhanced simulator function.

2.1 Applied Scenarios for Acceptance Test

In the first step, SKN 3&4 FAT(Factory Acceptance Test) and SAT(Site Acceptance Test) for verifying the applicability of the severe accident simulation and the severe accident response strategy and means.

The following table1 shows two scenarios for SKN3&4 simulator severe accident functional test.

Table I: Scenario main contents

No	Title	Main contents
1	Small Break Loss of Coolant Accident(SBLOCA) + Safety injection loss accident	° reactor shutdown by low pressure of pressurizer ° Loss of safety injection pump and charging pump ° Auxiliary feedwater pump operation failure ° Isolation of the reactor building by the occurrence of CIAS ° Perform the spray of the reactor building according to CSAS occurrence. ° Enter severe accident (reactor Exit Temperature 649°C) due to lack of heat removal means ° Hydrogen detector operation and hydrogen igniter startup ° Filling of primary-side coolant using RCS and spray pump of containment building
2	Station Black OUT(SBO)	° Loss of all offsite power, including EDG and AAC DG ° Turbine driven auxiliary feedwater pump operation failure ° Enter critical accident due to lack of heat removal means ° Medium (350 kW) Mobile Generator Connections ° Hydrogen detector operation and hydrogen igniter startup

		° RCS decompression by opening the safety relief valve ° External injection of the primary side coolant using a mobile pump car ° Perform the spray of the reactor building by using a mobile pump

2.2 Test procedure and Termination condition

Malfunction and Component malfunction are started according to scenario assumptions about 5 minutes after simulator startup. Subsequently, the charging pump and the safety injection pump are not operated according to the assumptions, and the SIT is isolated and the core cooling means is lost.

Initial measures such as shutting off the isolation valve of the containment building and preserving the inventory of the steam generator are carried out, but the level of the reactor vessel is depleted due to continuous RCS leakage and the temperature of the core outlet heat transfer unit rises as a result of exposure to the core and enters a severe accident. After entering the severe accident, operate the hydrogen monitor, start the hydrogen igniters, and start filling the RCS using a single series of spray pumps. The containment building pressure was reduced due to continuous filling to the RCS using the spray pump, and the core cooling was performed, and the pressure of the containment building was reduced due to continuous spray of the containment building, and the severe accident situation was mitigated

The conditions for the completion of the acceptance test are as shown in the table below.

Table II: Scenario termination condition

No.	parameter	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 980 cmH2Og (Spray ending condition)
3	Hydrogen concentration	Stabilized or reduced to less than 5% (Condition of termination of severe accident)

2.3 Result of Severe Accident Function Test

As a result of this scenario, it was verified that the containment building pressure and other major variables, such as temperature rise of the CET and increase of the pressure of the containment building, were adequately simulated, and the possibility of application of severe accident response strategies and means, such as filling the RCS using the spray pump, was verified after the accident entry. Finally, it was confirmed that the severe accident situation was mitigated by the severe accident response strategy. The graph of the main variables is shown below.

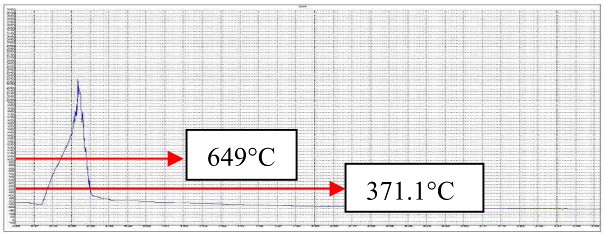

Fig. 1. CET temperature

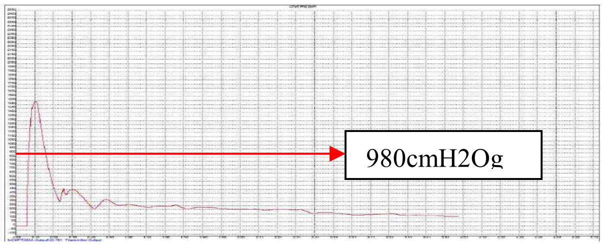

Fig. 2. Containment building pressure

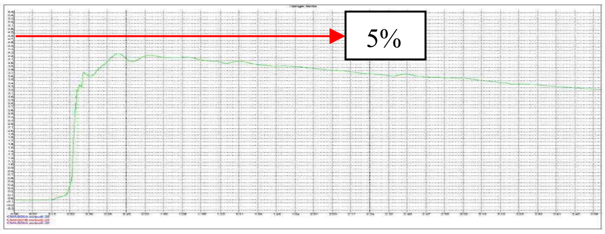

Fig. 3. Hydrogen concentration

3. Conclusions

The FAT and SAT performance tests carried out in step 1 confirmed that the severe accident situation was properly simulated and that the severe accident response strategies and means are applicable. In the second step, the simulator's severe accident functions will be enhanced through continuous strengthening and supplementing of severe accident functions, such as supplementing simulator modeling and developing training scenarios for severe accident exercise.

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*

[2] SKN3-SAMG-SAT-01~02, "Site Acceptance Test Procedure – SBLOCA, SBO", KHNP, 2020