Developing the Stress Test Gap Analysis Methodology for Nuclear Power Plants

Hun Jeong [a*], Bong-Yo Yun
[a]*KHNP Central Research Institute, Daejeon, 34101, Republic of Korea*
[*]*Corresponding author: jeonghun@khnp.co.kr*

1. Introduction

Korea had demonstrated the safety of long-term operational nuclear power plants by implementing stress test such as Wolsong-1 & Kori-1 unit. It was decided to extend the stress test to all the nuclear power plants in Korea. And KHNP is evaluating the capability of responding to the operational plant in the event of severe accidents that exceed the design basis. The stress test will be conducted in the first stage; conduct a representative nuclear power plant test for each reactor type, OPR1000, CANDU, Framatom, Westinghouse types, included partial of APR1400. Then residual nuclear plants will be implementing an effective assessment through a gap analysis. So the gap analysis methodology will be developed and used for stress testing. After that, nuclear power plants of the same type will be evaluated in the second stage.

2. Definition of the Stress Test Gap Analysis

Gap analysis is to derive the difference between the representative nuclear plant and the residual them. Basically, a nuclear power plant with the same reactor model shares the design. However, design changes may be different during the construction and operational processes. In addition, the design can be improved with the advancement of technology. Therefore, it is important to find differences in the factors that affect the test between the same reactor types. Based on the gap analysis, the stress test will be conducted effectively.

3. Stress Test Configurations

The stress test is defined as follows. It evaluates the safety margins of the plant in extreme natural hazards, including earthquake and tsunami, similar to the accident at Fukushima nuclear power plant.

Sections	Assessment Fields
1	SSC safety from the earthquake
2	SSC safety from the Tsunami etc
3	Response ability at SBO, loss of safety function
4	Severe accident management ability
5	Radiation emergency plan
6	Operation management

Table 1 The Assessment Fields of Stress Test

*SSC : Structure System Component
*SBO : Station Black Out

It consists of six detailed assessment fields for the effective performance of the test as shown in Table 1. All these sections will be used to evaluate all our nuclear power plants.[1]

4. Representative Nuclear Power Plant

There are various types of nuclear power plants in Korea; Pressurized Water Reactor(PWR), Pressurized Heavy Water Reactor(PHWR). Also, PWRs are classified as OPR, WH-2 loops, WH-3 loops, Framatom. It is difficult to conduct the stress test for these different types of the reactor in a short time.

Thus, it selects a plant that represents each type and implements the stress test. The representative plants are shown in Table 2.

However, assessment of representative power plants is not able to replace evaluations of all the same reactor types. The selection of a representative nuclear plant among different types of reactor types is the determination of criteria for the stress test.

<table>
<tr><td></td><td colspan="4">PWR</td><td>PHWR</td></tr>
<tr><td>Reactor Type</td><td>OPR</td><td>FRA</td><td>WH2</td><td>WH3</td><td>CANDU</td></tr>
<tr><td>REP NPP</td><td>HU3</td><td>HU1</td><td>KR2</td><td>HB1</td><td>WS2</td></tr>
<tr><td rowspan="2">1st Gap</td><td>O</td><td>O</td><td rowspan="2">-</td><td>O</td><td>O</td></tr>
<tr><td>HU4</td><td>HU2</td><td>HB2</td><td>WS3,4</td></tr>
<tr><td rowspan="6">RES NPP Assessment</td><td>HU5
HU6</td><td rowspan="6"></td><td rowspan="6"></td><td rowspan="6">KR3
KR4</td><td rowspan="6"></td></tr>
<tr><td>HB3
HB4</td></tr>
<tr><td>HB5
HB6</td></tr>
<tr><td>SK5
SK6</td></tr>
<tr><td>SW1
SW2</td></tr>
</table>

Table 2 Phase-by-stage classification of NPP[2]

※ OPR : KSNP, FRA : Framatom, WH2 : WH 2 loops, WH3 : WH 3 loops
※ HU : Hanul NPP, HB : Hanbit NPP, SK : SinKori, SW : SinWolsung
※ KR : Kori, WS : Wolsung,
※ REP NPP: Representative NPP, RES : Residual NPP

5. Gap Analysis Methodology

To analyze the gap between plants, the stress test analysis of the representative nuclear power plant should be completed.

5.1. Sections of Stress Test Gap Analysis

The Gap analysis does not apply to all of the areas shown in Table 1. The locations of the power plants are different. Since the location of the plants is different, the characteristics due to the geographical differences need to be analyzed separately. It has its own characteristics according to the geographical location of the power plant. Until now, it was a relatively stable country for earthquakes before Kyoungju earthquake in 2016. Since then, there have been numerous earthquakes in near areas, Kyoungju, Pohang.

In addition, there are geographical and climatic variations depending on the region. Depending on the location of the power plant, there will be differences in precipitation, storms, and tsunamis. Therefore, section 1 and 2 of the stress test does not perform difference analysis.

In section 3, response-ability at SBO, loss of the safety function, differences in plant accident response facilities and prevention facilities from the severe accident will be derived. In section 4, severe accident management ability, evaluates accident mitigation capabilities caused by differences in facility, design, and response strategies in the event of severe accidents. It also includes assessing capability for mitigating severe accident by using the severe accident analysis code such as MAAP(Modular Accident Analysis Program, EPRI).

In section 5, radiation emergency plan, evaluates the differences in response capabilities, according to the radiation emergency plan. In section 6, operation management, analyzes differences across operations due to differences in plant members, procedures application, and operating methods.

Based on these differences, the analysis determines the need for a stress test assessment of the residual plants. The analysis of these differences is documented with the evidence.

5.2. Definition of the Comparison Factors

From the gap analysis, the comparison factors that can influence the stress test should be derived. For instance, plants of the same type as the pressurized water reactor are based on essentially the same design. The same type of power plant located on the same site is expected to be no different. However, there may be differences in the design of the same type located on other sites, such as the improvement of the design and the introduction of improved equipment. Despite the same design in the event of extreme natural disasters, the availability of equipment at different sites is inevitably different. This fact has already been experienced in the accident at the Fukushima nuclear plant. These differences can be defined as comparison factors.

5.3. Gap analysis of Residual Nuclear Power Plants

After deriving the comparison factors, identify design differences in equipment that affect the comparison factors for the same reactor type. If there are no design differences in the factors, provide appropriate evidence for them.

On the other hand, if design differences can be identified for factors, the following procedure should be performed. Due to the design differences in the factors, it should be determined whether or not the results of the stress test evaluation can be affected. If the differences in the factors do not affect the stress test, the evidence should be clearly presented. However, if the factors can influence the assessment of stress test, a rationale is provided. It shall be identified when conducting residual nuclear plant stress test on the basis of this evidence.

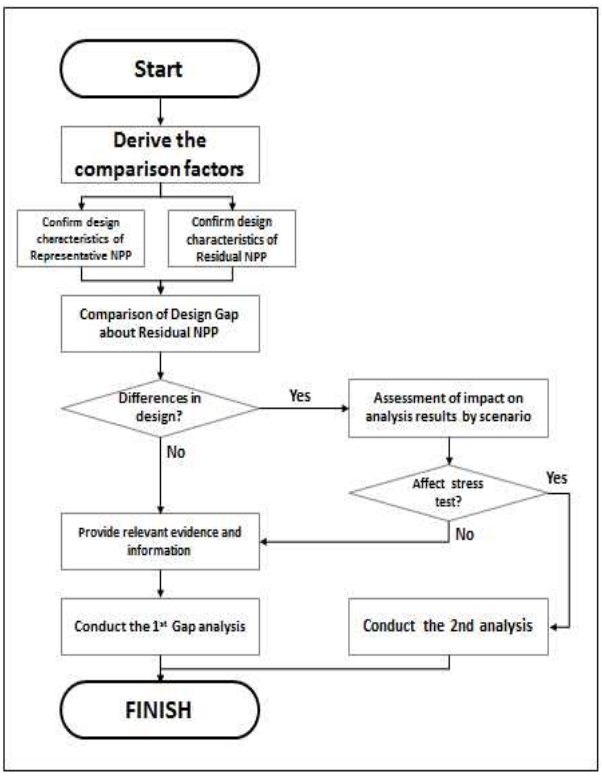

Fig.1. The Procedure of GAP analysis

The procedure of the gap analysis methodology is shown in Figure 1. The gap analysis will be conducted by that procedure, could become the most reasonable methodology. The differences will be intensively reviewed and analyzed during the next step of the analysis.

5. Conclusions

The public questioned the safety of nuclear power plant after the Fukushima accident. Korea has already proven the safety of nuclear power plant through conducting the stress test on the long-term operation.

Now a new challenge has begun. It will prove all of the nuclear power plants in Korea. As noted earlier, it is very difficult to conduct a stress test on an entire plant in a short time. The stress test is also more complicated in Korea, where various types of nuclear reactors are mixed up.

Under these difficult conditions, the methodology for the GAP analysis was developed for conducting the effective stress test. This can be a way to implement stress test successfully and efficiently. The newly established methodology will continue to improve. It will contribute to the safe and accurate stress test.

REFERENCES

[1] KINS, Guideline for Stress Test Status of Nuclear Power Plant in Operation, 2017.
[2] S.T. Yang, Stress Test Status of Nuclear Power Plant in Operation and The Strategy of Extreme Natural Disaster Response Strategy, Nuclear Safety & Security Information Conference, 2017.