Selection of reference scenario for SMART based on risk-informed analysis methodology

Sung-won Lim[a*], In-sub Jun[a], Young-jong Chung[a]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeokdaero, Yuseong, Daejeon, 305-353, Republic of Korea*
[*]*Corresponding author: sw54176@kaeri.re.kr*

1. Introduction

To provide regulatory guidelines for an advanced reactor licensing, the regulation authorities have been developing a analysis methodology based on risk-informed technology. In accordance with the regulatory trend, KAERI has developing a analysis methodology based on risk-informed technology.

As a part of the development, feasibility of the methodology is evaluated with accident scenarios of SMART. In this study, the reference scenarios are selected. And frequencies of the scenarios are calculated from initial accident frequency and failure probabilities of safety elements.

2. Feasibility Evaluation with SMART

The risk-informed analysis methodology that has developing was evaluated with 3 steps.

(1) Step 1: Reference scenario selection and frequency quantification
(2) Step 2: Analysis for reference scenario
(3) Step 3: Radioactive consequence analysis for reference scenario

Among the steps, the first step composed of 4 sub-steps.

(1) Sub-step 1: Frequency quantification of initial accident
(2) Sub-step 2: Scenario development from safety elements
(3) Sub-step 3: Reference scenario selection
(4) Sub-step 4: Frequency quantification of reference scenario

2.1 Frequency quantification of initial accident

In this study, SBLOCA was selected as initial accident. The SBLOCA is an accident that primary coolant inventory is decreased by failure of pressure boundary. The frequency of the accident was evaluated as *3.97E-03/RY* [1].

2.2 Scenario development from safety elements

The SMART has several safety features that stabilize abnormal transients of reactor system. The initial accident, SBLOCA would be stabilized by the safety features. Thus the safety features that involved in the transient should be considered as parts of accident scenario. Here are the safety features that involved in the transient [2].

(1) Reactor Trip: In case of SBLOCA, the primary pressure drops due to primary coolant discharge. Thus the reactor is tripped by low pressure signal.

(2) RCS makeup by SIS: The primary pressure keeps decreasing after reactor trip. Thus the safety injection system is activated soon. The coolant of IRWST is injected into reactor vessel through safety injection pumps.

(3) Feedwater supply: In case of SBLOCA, secondary system is available when off-site power is available. Therefore the residual heat of primary system can be removed by feedwater supply.

(4) PRHRS: PRHRS is a unique safety feature of SMART that removes residual heat by natural circulation. The residual heat of primary system can be removed by the PRHRS.

(5) Safety Depressurization: SMART has safety depressurization system that decreases primary system pressure rapidly. Thus the abnormal conditions that is induced by SBLOCA can be stabilized by feed and bleed operation.

(6) RCS makeup by SCS pumps: The SCS has equipped pumps that could inject coolant from IRWST to pressure vessel. Thus the pumps of SCS can be used for coolant injection at low primary pressure condition.

(7) IRWST Cooling: The coolant of IRWST is used for heat sink of PRHRS as well as sources for coolant injection by SIS and SCS. Thus IRWST cooling has to be considered at analysis. The coolant of IRWST is chilled by containment spray system heat exchanger.

These safety features that involved in the transient are called as safety elements. And specific accident scenarios are developed from these elements. Accident scenarios for SBLOCA of SMART are shown as fig. 1. The items on the first row indicate the safety elements of SBLOCA. And the numbers on right side means scenario sequence number. The state means the consequential results for each scenario.

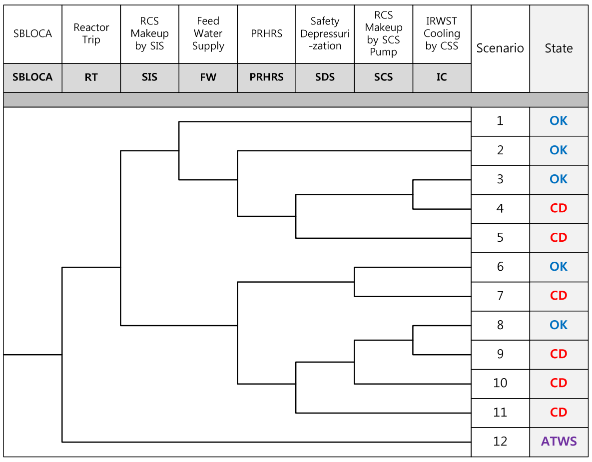

Fig. 1. Accident scenarios for SBLOCA of SMART. (OK: no core damage, CD: core damage, ATWS: anticipated transient without scram)

2.3 Reference scenario selection

Among the scenarios, two reference scenarios are selected for feasibility study.

(1) Scenario #2

In this scenario, the reactor trip function and safety injection system operate properly. However, the feedwater supply is not available. Thus, PRHRS is activated for residual heat removal. Because of SIS and PRHRS operation, the reactor system is stabilized safely without any other safety actions.

(2) Sequence #6

In this scenario, the reactor trip function operates properly. However, the SIS is failed to operate. Thus, residual heat of primary system is removed by PRHRS, and then pumps of SCS inject coolant into the vessel. The reactor system is stabilized by SCS and PRHRS with no core damage.

2.4 Frequency quantification of reference scenario

The frequency of scenario is quantified from initial accident frequency and failure probabilities of safety elements. The frequencies of the reference scenarios are quantified as below.

$$Frequency(\#2)=(SBLOCA)\times(1-RT)\times(1-SIS)\times(FW)\times(1-PRHRS) \quad (1)$$

$$Frequency(\#6)=(SLOCA)\times(1-RT)\times(SIS)\times(1-PRHRS)\times(1-SCS) \quad (2)$$

Here by,

SBLOCA = Initial accident frequency
RT = Failure Probability of reactor trip
SIS = Failure Probability of SIS
FW = Failure Probability of feedwater supply
PRHRS = Failure Probability of PRHRS
SCS = Failure Probability of SCS

From the equations, the frequencies of reference scenarios are calculated as *1.115E-04/RY* and *2.801E-07/RY*.

3. Conclusions

The reference scenarios for feasibility evaluation of risk-informed analysis methodology are selected based on risk-informed methodology. And the frequencies of reference scenarios are quantified from the initial accident frequency and failure probabilities of safety elements. These scenarios and its frequencies will be utilized for further steps of evaluation.

NOMENCLATURE

KAERI, Korea Atomic Energy Research Institute
PRHRS, Passive Residual Heat Removal System
RCS, Reactor Coolant System
SBLOCA, Small Break Loss of Coolant Accident
SCS, Shutdown Cooling System
SIS, Safety Injection System

REFERENCES

[1] T. W. Kim, Evaluation Report for Initial Accident of SMART, 916-NS301-001, KAERI, 2010.
[2] T. W. Kim, Evaluation Report for Event Tree of SMART, 916-NS301-002, KAERI, 2010.