Regulatory Code System Configuration for DNBR Evaluation on the Asymmetric Events with High Burn-up Fuel Issues

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1. Introduction

SRP chapter 15 in USNRC is played a key role in providing a licensee with acceptance criteria and requirement of design in nuclear industries. Especially, evaluation of LOCA have been analyzed results of the accident, the quantification of uncertainty and providing its conservatism using the realistic evaluation method so far. KINS which is the regulatory body in Korea have used the KINS-REM based on CSAU to evaluate LOCA [1]. However, because there are many types of non-LOCA transient scenarios, it is difficult to apply to non-LOCA like LOCA using realistic evaluation method directly.

As concern on the nuclear safety is getting more increased by the public and it is raising safety issue on the high burnup fuel in worldwide, it has possibility highly to submit operating licensing or amendment as a type of realistic evaluation method for non-LOCA transients. So, in order to prepare the future regulatory demands or needs, it is needed to develop the overall framework for non-LOCA evaluation method in Korea.

This study is to develop an evaluation methodology for Non-LOCA and construction of the code system for asymmetric events which are essential in transient.

2. Overall Framework for Non-LOCA

Non-LOCA framework is fundamentally based on KINS-REM, but it is applied to several items changed to enhance the efficiency of evaluation considering unique feature which is short transient duration and simplicity. Major changes in compared to LOCA evaluation method are followed;

1) the use of the latest system code such as MARS-KS ver. 1.5 to consider the accuracy and efficiency.
2) the exception of the quantity of uncertainty in many parameters in order to consider cost-benefit.
3) reflection the real plant configuration as a base case and consideration of conservative initial conditions and assumptions.
4) external interconnecting of regulatory codes from fuel to system.

Table 1 shows the overall framework for non-LOCA comprised of 9 steps.

Table 1. Overall Framework for non-LOCA

Step	Contents
1	determination of event scenario; selection of event sequence that is willing to analyze
2	selection of plants; selection of plant that is willing to analyze
3	making a PIRT; verification and classification of important phenomena to each event
4	specifying codes; specifying codes
5	codes assessment; requirements vs. code capabilities
6	defining NPP modeling and nodalization; BOP modeling and its node defining
7	base calculation of the NPP; construction of base decks for non-LOCA (steady and transient)
8	sensitivity analysis; reasonable conservative assumptions and initial conditions
9	final assessment of the events; final assessment by comparing FSAR or another code results.

3. Asymmetric Events through the PIRT

It spends a lot of time and cost for applying to KINS-REM perfectly, but PIRT (Phenomena Identification and Ranking Table) is one of the beneficial ways to get the insight for Non-LOCA. So, this study performs to develop the PIRT to be provided analysis methodology and to be extracted asymmetric events.

PIRT developed in this study is specified important phenomena fully considering acceptance criteria defined in regulatory law and guide. 5 acceptance criteria and 12 important phenomena are described in this study [2].

Concern on the asymmetric phenomena in core region have been increased as safety issues that are highly possible to significantly reduce the thermal margin. It is because of the considerable asymmetric balance of core mass flow, temperature, pressure and reactivity. 3 asymmetric events are selected by PIRT among the 27 events; they are a main steam line break, locked rotor and an inadvertent decrease in boron concentration.

MSLB is the over-cooldown transient with rapidly increasing mass steam flow to be caused asymmetric core temperature. The main concern is the possibility whether core can reach the re-criticality when the core has the asymmetric distribution thermally. The locked rotor has the representative asymmetric phenomena aspect to the balance of mass flow rate. This event can cause the decreasing of mass flow and severely cause the asymmetric mass flow in the core bottom. The inadvertent decrease in boron concentration is one of the abnormal reactivity events and this can cause the partial insertion of reactivity due to absent of boron in the coolant. It is necessary to use the 3-dimensional fluid dynamics to precisely identify the region where boron is not or less. Fig. 1 show the example of results in selection as asymmetric events.

SRP	Asymmetric Events		
	15.1.5	15.2.8	15.3.4
Criteria			
DNBR(Core)	1		1
FCM(Rod)	2		
Primary Pressrue	2	1	1
SG Pressure		2	
Enthalpy Deposition			
Key Phenomena			
Core TH	1	2	2
Kinetics Feedback	1	2	2
Strutural Heat and Heat Loss	1	2	
Pressurizer	1	1	1
Surge Line Hydraulics	2	1	
Pump Behavior	2	2	1
Boron Tracking	1		
SG Pri/Sec HT	2	1	1
SG Secondary	2	2	
Critical Flow	1	1	
Natural Ciculation	2	1	1
Core-Loop Mixing	1	2	1

Fig. 1. Events selected as asymmetric events.

4. Code System to Evaluate Asymmetric Events

It will be used to evaluate the asymmetric events at least with 3 different codes; system code, computational fluid dynamics software, sub-channel analysis code. First, it will be analyzed system behavior of asymmetric events using the system code such as MARS-KS or TRACE. The main information is mass flow rate, temperature and pressure in the cold-leg and hot-leg where it is essential to evaluate asymmetric phenomena in the core region while it experiences transient. Commercial CFD software will calculate the distribution of mass flow rate in the core bottom based on the information from the results of system code. This step is able to identify the 3-dimensional distribution of coolant in the core bottom. So, it plays a key role in making a decision to perform how to model into sub-channel analysis. Finally, CTF which is sub-channel analyzer for DNBR will precisely evaluate DNBR and thermal margin based on the asymmetric mass flow rate and temperature.

Additionally, it needs peak factor and power distribution of each fuel assembly or rod to consider the high burn-up issue when DNBR is evaluated by CTF. PARCS, FRAPCON and FRAPTRAN will sometimes be used to generate the necessary information in case of high burn-up cases. Fig. 2 shows the code system to evaluate the asymmetric events.

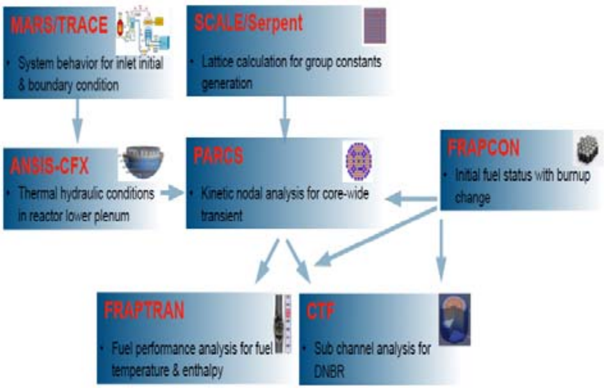

Fig. 2. Code system configuration

5. Conclusions

This study presents the overall framework and regulatory audit methodology to evaluate the Non-LOCA with results of PIRT. The framework developed under the principle of more efficiency and cost-benefit considering the feature of the Non-LOCA. 3 asymmetric events among the 27 transients according to SRP [3] are selected from the PIRT comprised of 5 acceptance criteria and 12 important phenomena; main steam line break, locked rotor and the inadvertent decrease in boron concentration.

3 different codes including 3-dimensional fluid dynamics will be used at least to evaluate the asymmetric events from system behavior to sub-channel analysis and will be also used PARCS, FRAPCON and FRAPTRAN to generate the information for the precise analysis of sub-channel in case of high burn-up fuel. It is able to evaluate all of the transients including asymmetric events according to SRP with the combination of the code system discussed in this study.

REFERENCES

1. I. S. Lee, “Advance of Regulatory audit methodology of Design Basis Accident,” KINS/RR-1856, KINS (2018).
2. K. R. Greene, “Utilizing Elements of the CSAU PIRT to Qualify a PWR Non-LOCA transients System Code”, Framatome ANP.
3. USNRC, “Standard Review Plan for the review of safety analysis report for NPP”, NuREG-0800 (2007).