KHNP
KOREA HYDRO & NUCLEAR POWER CO., LTD

Enclosure 3

Response to Discussion Initiators for KHNP/NRC Reactor Systems
Public Teleconference

(Non - Proprietary)

October 27, 2015

Non-Proprietary

Response to Discussion Initiators for KHNP/NRC Reactor Systems Public Teleconference: October 28, 2015

A. Non-LOCA Safety Analysis Topics (60 minutes)

(Tim Drzewiecki)

1. Radial peaking iteration

Background

In performing the transient analyses in Chapter 15, parametric studies are performed to determine the set of initial conditions that produce the limiting result (e.g. minimize DNBR). DCD Table 15.0-3 identifies plant initial conditions and their ranges. In addition to the parameters identified in DCD Table 15.0-3, the safety analysis includes the radial peaking factor, F_r, in the parametric study (see response to RAI No. 139-8084 Question No. 15.03.01-1). This has cause NRC staff to question how the radial peaking factor is obtained a priori.

Requested Input from KHNP

a. Explain how the radial peaking factor, corresponding to the set of initial conditions, is obtained for use in the safety analysis.
b. Provide a list identifying the parameters included in the parametric studies

<u>Response</u>

a. First, KHNP need to find out the set of limiting condition of operation (LCO). The required over power margin (ROPM) set aside by the Core Operating Limit Supervisory System (COLSS) is greater than | |^{TS} during normal operation. It means that if the core power increase from 100% to | |^{TS} and the other parameters do not change, then this condition makes the DNBR equal to the DNBR SAFDL. It can be found out the initial Fr by using the CETOP code at a chosen core flow rate, inlet temperature, pressurizer pressure, bottom-peaked axial shape and the heat flux corresponding to 100% power multiplied by the ROPM until the MDNBR reaches the DNBR SAFDL. Examples are as below:

TS

b. Please see the list of the parameters included in the parametric studies below;

Parameter	Units	Range
Core power	% of 3,983 MWt	102
Axial shape index	-	-0.3 < ASI < +0.3
Reactor core mass flow	% of 161.6x106 lbm/hr	95 (minimum) 116 (maximum)
Core inlet coolant temperature	^{o}F	550 (minimum) 563 (maximum)
Pressurizer pressure	psia	2,175 (minimum) 2,325 (maximum)

2. 11% Excore Penalty

Background

The variable overpower trip (VOPT) as modeled in CESEC-III includes an 11% excore power penalty (see APR1400-F-A-TM-12009, Rev. 0, “APR1400 NRC DC – Barrier Performance Analysis for CEA Ejection Accident”). This caused NRC staff to question the basis for the 11% penalty.

Requested Input from KHNP

a. Explain the basis for the 11% excore penalty for the VOPT trip as modeled in CESEC-III.

Response

The value 11% is identical to the value used for CEA ejection analysis for the System 80+ Advanced Light Water Reactor (ALWR), which was already approved by the NRC. When CEA ejection occurs, two excore detectors near the ejected CEA respond immediately, but the other two do not. To consider these two excore failure detectors near the ejected CEA, the same amount of excore power penalty to the VOPT trip setpoint is applied.

3. ASI Conversion to Power Shape for Safety Analysis

Background

The axial shape index (ASI) is stated to vary between -0.3 and +0.3 in DCD Table 15.0.3 and Table 2.2.1 of the non-LOCA Technical Report. However, it is not clear how the ASI in converted into an axial power shape for use in safety analysis (CESEC-III and CETOP).

Requested Input from KHNP

a. Provide an explanation, equation, or figure (equation would be best) to describe the conversion from ASI to the axial power shape used in the safety analysis.
b. Explain why the power shape is an accurate or conservative representation of the actual power shape.

Response

There is no conversion equation or figure from the axial shape index (ASI) to the axial power shape. The ASI is the power generated in the lower half of the core minus the power generated in the upper half of the core, divided by the sum of the power generated in the lower and upper halves of the core [DCD TS 1.1 Definitions]. ASI value just represents the form of the axial shape. The possible axial shapes are generated to cover all conditions of the operation considering PDIL, power level and burnup by using the free xenon oscillation method. Axial shape package contains about 8,000 axial shapes, and it can be possible to distinguish the shape or make a group using ASI. The conservative axial shape among the same ASI group is chosen during safety analysis stage.

4. Steam Generator Inventory Vs Level

Background

DCD Table 15.0-3 and Table 2.2-1 of the non-LOCA Technical Report provide the initial steam generator water level range assumed in the safety analysis (i.e. inventory in terms of level). However, the individual events provide the initial steam generator inventory in terms of mass. NRC staff needs to verify that the initial conditions are appropriate for each event.

Requested Input from KHNP

a. Provide an explanation, equation, figure, or table (equation would be best) to describe the conversion from steam generator level to steam generator inventory (in terms of mass).

Response

The CESEC-III uses SG mass inventory for calculations. Therefore, the initial SG level condition for each non-LOCA event is provided as SG mass inventory corresponding to the initial SG level for the CESEC-III input. This SG mass inventory is calculated by interpolation using the relevant data (Power vs. SG level vs. SG mass inventory) as shown in Table 1.

5. Pressurizer Inventory Vs Level

Background

DCD Table 15.0-3 and Table 2.2-1 of the non-LOCA Technical Report provide the initial pressurizer water level range assumed in the safety analysis (i.e. inventory in terms of level). However, the individual events provide the initial pressurizer water volume. NRC staff needs to verify that the initial conditions are appropriate for each event.

Requested Input from KHNP

a. Provide an explanation, equation, figure, or table (equation would be best) to describe the conversion from pressurizer water level to pressurizer water volume.

Response

The CESEC-III uses PZR water volume for calculations. Therefore, the initial PZR level condition for each non-LOCA event is provided as PZR water volume corresponding to the initial PZR level for the CESEC-III input. This PZR water volume is calculated by interpolation using the relevant data (PZR level vs. water volume) based on Figure 1.

B. Annealing Functions for Core Protection Calculator System (CPCS) and Core Operating Limit Supervisory System (COLSS) (30 minutes)

a. The staff has been reviewing the related submittals and ERR documents but has not yet been able to gain a clear and consistent understanding of how shape annealing functions and related inputs are determined and used.

b. Are there additional documents that could be submitted or added to the ERR that provide clearer and more comprehensive discussions of these topics?

Response

To generate axial power distributions, COLSS and CPCS use in-core detector signals and ex-core detector signals, respectively. Since COLSS axial power distribution is generated by Fourier synthesis method directly using the in-core detector signals, shape annealing function is not used in COLSS.

The CPCS axial power distribution is synthesized from response of the three element ex-core detector string. Figure 2 shows the calculation flow of CPCS axial power distribution. SAM (Shape Annealing Matrix) and BPPCC (Boundary Point Power Correlation Coefficients) are applied to the normalized 3-level ex-core detector signals to give 3-level peripheral power integrals (See Figure 3).

The shape annealing factors (SAM and BPPCC) are measured during startup test by comparing in-core power distributions and ex-core detector responses during a free xenon oscillation. Then the measured SAM and BPPCC are installed to CPCS to generate axial power distribution. This test is described in APR1400 DCD Tier 2 Chapter 14.2.12.4.12 (Verification of Core Protection Calculator Power Distribution Related Constants Test) and Table 14.2-4 (Power Ascension Test).

There are no additional documents that could be submitted.

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Table 1. SG Secondary Steam & Water Weights

100% WR (with maximum tube plugging)

TS

Normal Water Level (with maximum tube plugging)

TS

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50% WR (with maximum tube plugging)

TS

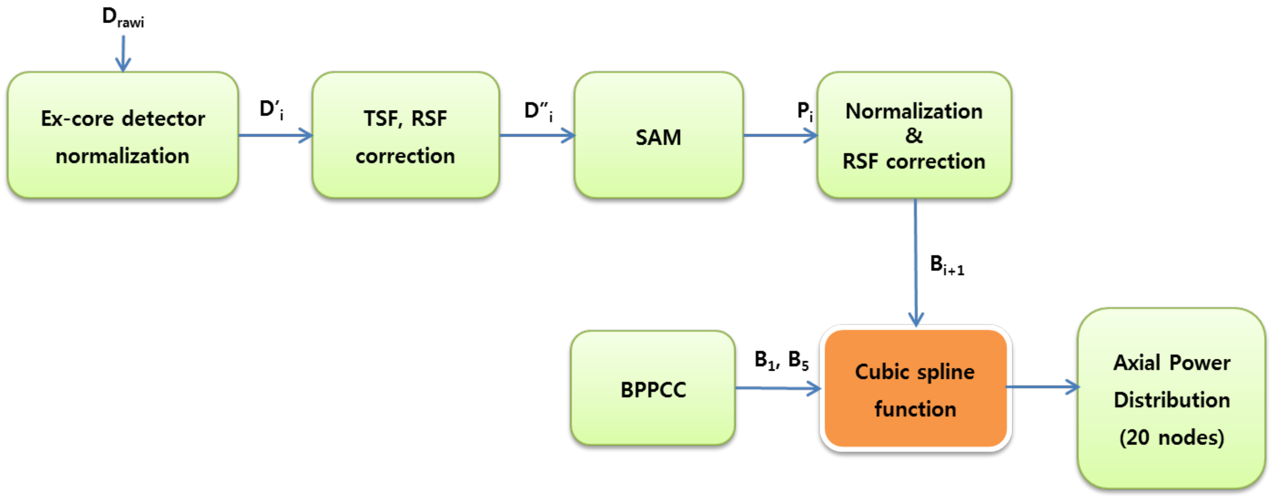
25% WR (with maximum tube plugging)

TS

0% WR (with maximum tube plugging)

TS

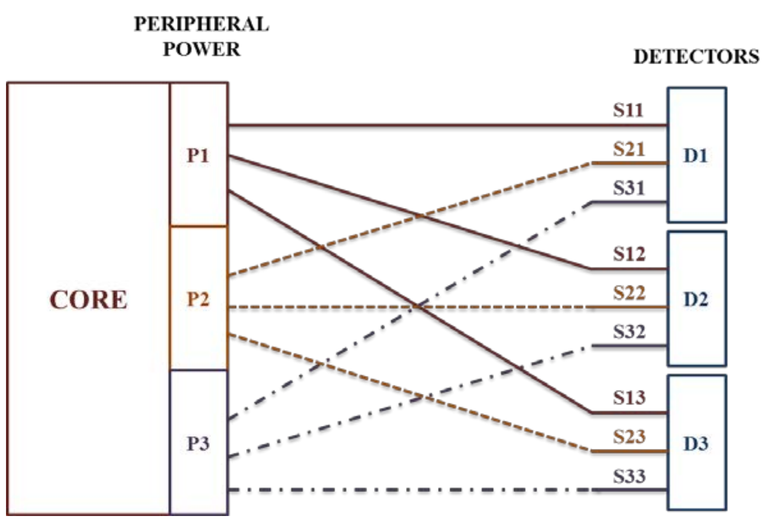
Figure 1. Pressurizer Level vs. Water Volume



Where,

Drawi	:	Raw excore detector signals
TSF	:	Temperature Shadowing Factor
RSF	:	Rod Shadowing Factor
SAM	:	Shape Annealing Matrix
BPPCC	:	Boundary Point Power Correlation Coefficient

Figure 2. Calculation Flow of CPCS Axial Power Distribution



$$\begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix} \begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix}$$

Figure 3. Shape Annealing Matrix (SAM)