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Preparation of Input Deck to analyze the Nuclear Power Plant for the Use of Regulatory Verification

Doohyuk Kang[a*], Hyungseok Kim[a], Jaeseung Suh[a], Seunghoon Ahn[b], Yongjin Cho[b]
[a]*ENESYS Co., 328, Guan-dong, Yuseong-gu, Daejon, 305-800, Korea*
[b]*Korea Institute Nuclear Safety, 19 Kusong-dong, Yuseong, Daejeon, 305-338, Korea*
[*]*Corresponding author: dhkang@enesys.co.kr*

1. Introduction

The objectives of this paper are to make out the input deck that analyzes a nuclear power plant for the use of regulatory verification and to produce its calculation note. We have been maintained the input deck of T/H safety codes used in existing domestic reactors to ensure independent and accurate regulatory verification for the thermal-hydraulic safety analysis in domestic NPPs.

This paper is mainly divided into two steps: first step is to compare existing input deck to the calculation note in order to verify the consistency. Next step is to model 3-dimensional reactor pressure vessel using MULTID component instead of the 1D existing input deck.

2. Methods and Results

In this section, we will describe the procedure of preparation of the input deck for the use of regulatory verification. Also, we will show the results of the steady state calculation about the 3D input deck by using the MULTID component for kori unit 1.

2.1 Procedure for preparation of input deck

The input deck of the NPP analysis for the use of regulatory verification has been prepared through follow the procedure.

1) Acquisition of the existing input deck: It obtained the input deck, calculation note, final report as the findings of the project "Development of best-estimate analyzer for PWR"[1].
2) Verification of the existing input deck: It verified the consistency between the results of the steady state calculation for the input deck and the operation data of a NPP.
3) Review and Modification of the calculation note for the input deck: first of all, to compare the consistency between the value of the calculation note and the value of the input deck. If there is a point of difference, we performed the careful analysis about the difference. Last, we modify the wrong value of the input deck.
4) Conversion of 3D core: a part of the core and reactor vessel included the existing input deck is converted from 1D input deck to 3D input deck. And, it prepared the calculation note for the 3D input deck.
5) Verification: The completed input deck was evaluated to verify the consistency between the results of a steady state of the completed input deck and a NPP condition. If the result is not satisfied, re-performing the procedure of (2), (3), and (4), we provides the satisfied results.

2.2 Scope of development

The input deck for the use of regulatory verification has been prepared for only PWR except the PHWR in domestic. The representative NPP is as follows.

- Westinghouse 587 : KORI unit 1
- Westinghouse 650 : KORI unit 2
- Westinghouse 950 : KORI unit 3&4
- Framatome 950 : ULCHIN unit 1&2
- OPR1000 : ULCHIN unit 3&4

This paper dealt with the kori unit 1. The other NPP will be dealt for the future.

2.3 Verification of 1D input deck

Numerous errors have discovered over the 1D input deck and the calculation note. The discovered errors were modified correctly.

2.4 Modeling for 3D input deck

The 3D input deck was converted for the part of the core, reactor pressure vessel using the verified 1D input deck. The conversion of the 3D input deck was modeled using the MULTID component classifying the multi-dimensional thermal-hydraulic volume, heat structure, and fuel.

To model the multi-dimensional T/H volume, the reactor pressure vessel was modeled with 5 radial rings, 8 azimuthal sectors, and 23 axial nodes. Here, the axial node of each component was based on the verified 1D input deck. The core region possesses 4 radial, 8 azimuthal, 14 axial grids. Is is assumed that the fuel assemblies are homogeneously distributed only in inner 3 radial grids. The outer 1 radial grid region is modeled as the core bypass. The outer-most 1 radial grid is used for the downcomer region.

To model the multi-dimensional heat structure, the heat structure corresponding to the multi-dimensional T/H volume was modeled again for the multi-dimensional reactor pressure vessel.

To model the multi-dimensional fuel, the core region was modeled with 32 heat structures for an assembly located in the given rings and sectors. The average rod was simulated in inner 3 rings and 8 sectors. The hot rod was also simulated in inner-most ring and 8 sectors.

Fig. 1 shows the cross-sectional diagram of the multi-dimensional node for the reactor pressure vessel of kori unit 1.

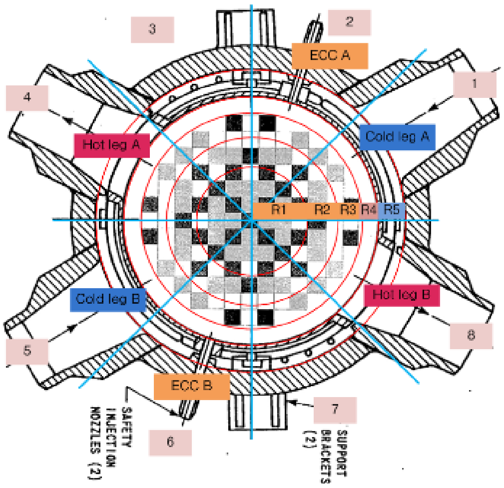

Fig. 1. Cross-sectional diagram of the multi-dimensional node for the reactor of kori unit 1

2.5 Result

To verify the consistency between the value of the original 1D calculation and the value of the verified 1D calculation, the steady-state calculation of the verified 1D input deck was performed for 300 seconds.

Table I: The comparison of the result for the calculation

	Plant Parameter	Design	Original 1D Calculation	Verified1D Calculation	3D Calculation	3D Error(%)	3D remark
Reactor	Core Power [MWt]	1723.5	1723.5	1723.5	1723.5	0.0	
	Reactor Pressure Drop [bar](10% Tolerance)	2.399	2.485	2.805	1.719	38.7	C170501190 -C30001
	Guide Tube Flow (through C250 : 0.28%)[kg/s] *	25.97	26.87	26.95	-	-	-
	Core By-Pass Flow (through C180 : 3.03%)[kg/s] **	281.03	280.64	269.68	168.84	37.4	C170401172 to C170401181
	Fuel Assembly Pressure Drop[bar](10% Tolerance)	1.379	1.411	1.765	1.973	-11.8	C170101030 -C170101180
Primary Side	Loop 1 Flowrate (BE)[kg/s]	4637.43	4637.1	4633.5	4910.5	-6.0	C485
	Hot Leg Temperature[k]	590.99	591.26	591.43	589.99	0.2	
	Cold Leg Temperatrure[K]	557.48	557.69	557.92	558.18	0.0	
	Temperature Rise [K]	33.51	33.57	33.51	31.81	5.1	
	PZR Level [%]	55	55.4	55.9	59.715	-6.8	
	PZR Pressure [bar]	155.11	155.1	155.1	155.1	0.0	
	Pump Head [m]***	79.86	70.1	53.09	46.34	12.7	
	Pump Torque [Nm]***	35904	32138	32147	30851	4.0	
	Pump Speed [RPM]	1190	1190	1190	1190	0.0	
	Primary Side SG Pressure Drop [bar] (10% Tolerance)	2.16	2.269	1.897	2.123	-11.9	C43000 -C45000
Secondary Side	Feedwater Flowrate[kg/s]	473.75	473.94	473.52	473.67	0.0	
	Steam Flowrate [kg/s]	473.75	473.94	473.64	474.03	-0.1	
	Steam Pressure [bar]	56.95	56.95	57.25	57.25	0.0	
	SG Level [%] (WR)	56.2	56.16	56.24	56.22	0.0	
	SG Recirculation Ratio +	2.8	2.99	2.99	2.99	0.0	3.7*(C61003 /C64001)

The result of the verified 1D calculation was well matched when compared to those of the original 1D calculation. But, the value of the pump head of the verified 1D calculation is smaller than the original 1D calculation. The reason was estimated that the loop system was changed because of SG replacement. So, it will be more needed an investigation.

To verify the consistency between the values of the 3D calculation and those of the verified 1D calculation, the steady-state calculation of the 3D input deck was performed for 300 seconds. The results of the 3D calculation are shown in table 1. The primary flow rate of the 3D calculation is greater than that of the verified 1D calculation. The reason for this difference is the temperature change at the hot-legs and the cold-legs. The reason for temperature change will be needed an investigation in further work.

3. Conclusions

We are performed the verification work to make out the input deck that analyzes a nuclear power plant for the use of regulatory verification and to produce its calculation note. To do this work, we have been maintained the input deck of T/H safety codes used in existing domestic reactors to ensure independent and accurate regulatory verification for the thermal-hydraulic safety analysis in domestic NPPs. Therefore, we will be accomplished the remained works in future.

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