The Status that the program to relieve set-point for the number of operable ICIs is applied to OPR1000

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1. Introduction

The Core Operating Limit Supervisory System (COLSS) of OPR1000 monitors in-core neutron power distribution, Linear Heat Rate (LHR) and Departure from Nucleate Boiling Ratio (DNBR) using In-Core Instrumentation (ICI). It is required that above 75% of ICI be operable to perform this functions [1]. 45 EA strings of ICI have been installed and operated in Hanbit #3, 4, 5, 6 and Hanul #3, 4, 5, 6. Their signals are transferred to Plant Monitoring System (PMS) via four Plant Data Acquisition System (PDAS) channels. PMS includes a few application programs like COLSS. In a case that one of 4 PDAS channels fails, COLSS is inoperable. It means that reactor power should be reduced and monitored by CPCS [1] because FSAR [2] of OPR1000 requires that 75% ICIs should be operable. This action can induce transient of reactor core. In order to complement such a trouble, KHNP, KEPCO NF and KEPCO ENC have proposed the way that COLSS can be operable though operable ICIs exist between 60% ~ 75%. That way is licensed and applied to Hanbit #3, 4, 5, 6 and Hanul #3, 4, 5, 6. In this paper, the methodology and status that applied to following units are described.

2. Methodology and Results [3]

In cases that above 25% ICIs are inoperable, power distribution are analyzed like following sequence;

① Obtaining Snapshot file in the steady state.

② Generation of reference power distribution using the Snapshot file and CECOR code.

③ The calculation of COLSS/CPC power distribution Root Mean Square (RMS) Error using CEFAST Code.

④ Checking the operation variables like DNBR-POL, LHR-POL, ASI and TILT and so on. (Case 1, COLSS1)

⑤ COLSS power distribution RMS Error using off-line COLSS FORTRAN Code and CECOR Code. (Case 2, COLSS2)

⑥ Run off-line COLSS FORTRAN Code with assuming ICIs to be failed like follows;

A. All ICIs of PDAS Ch. A are inoperable (Case 3, COLSS3)

B. 50% ICIs are inoperable

- All ICIs of PDAS Ch. A are inoperable and additionally random failure (Case 4, COLSS4)
- Random failures of 50 % ICIs (Case 5, COLSS5)

⑦ The Calculation of power distribution RMS Errors for reference power distribution

The data of 4 units were analyzed with above method and the results are follows;

Table1 Unit 1 Data

	TILT	LHRPOL	DNBRPOL	ASI	RMS Error
CECOR	0.0018	*	*	0.0206	-
CPC A	-	-	-	0.0278	2.619
CPC B	-	-	-	0.0227	2.628
CPC C	-	-	-	0.0104	2.962
CPC D	-	-	-	0.0388	4.142
Case 1**	0.0051	123.956	104.787	0.0149	2.134
Case 2**	0.0048	123.924	104.793	0.0152	2.194
Case 3**	0.0049	123.804	104.793	0.0160	2.249
Case 4**	*	*	*	0.0074	2.417
Case 5**	*	*	*	0.0171	2.403

Table2 Unit 2 Data

	TILT	LHRPOL	DNBRPOL	ASI	RMS Error
CECOR	0.0060	*	*	0.0157	-
CPC A	-	-	-	0.0070	9.097
CPC B	-	-	-	0.0202	8.979
CPC C	-	-	-	0.0315	8.992
CPC D	-	-	-	0.0061	8.499
Case 1	0.0082	118.346	101.224	0.0142	3.265
Case 2	0.0073	118.542	100.983	0.0139	3.256
Case 3	0.0097	118.357	100.983	0.0140	3.216
Case 4	*	*	*	0.0189	3.476
Case 5	*	*	*	0.0177	3.272

Table3 Unit 3 Data

	TILT	LHRPOL	DNBRPOL	ASI	RMS Error
CECOR	0.0067	*	*	0.0180	-
CPC A	-	-	-	0.0398	3.084
CPC B	-	-	-	0.0506	3.835
CPC C	-	-	-	0.0072	2.037
CPC D	-	-	-	0.0188	1.877
Case 1	0.0072	133.606	111.699	0.0290	1.611
Case 2	0.0071	133.635	111.450	0.0290	1.686
Case 3	0.0050	133.902	111.699	0.0290	1.741
Case 4	*	*	*	0.0217	2.499
Case 5	*	*	*	0.0319	1.856

Table4 Unit 4 Data

	TILT	LHRPOL	DNBRPOL	ASI	RMS Error
CECOR	0.0041	*	*	0.0000	-
CPC A	-	-	-	0.0480	5.086
CPC B	-	-	-	0.0358	4.072
CPC C	-	-	-	0.0516	5.623
CPC D	-	-	-	0.0386	4.258
Case 1	0.0045	129.707	108.451	0.0126	2.130
Case 2	0.0046	129.732	107.969	0.0126	2.113

Case 3	0.0050	129.895	107.949	0.0128	1.985
Case 4	*	*	*	0.0050	1.904
Case 5	*	*	*	0.0151	2.151

* In a case that 50% ICIs are inoperable, COLSS can't calculate TILT, LHR-POL and DNBR-POL.

** Case i ≡ COLSS i

Figure 1 Power distribution for unit 1

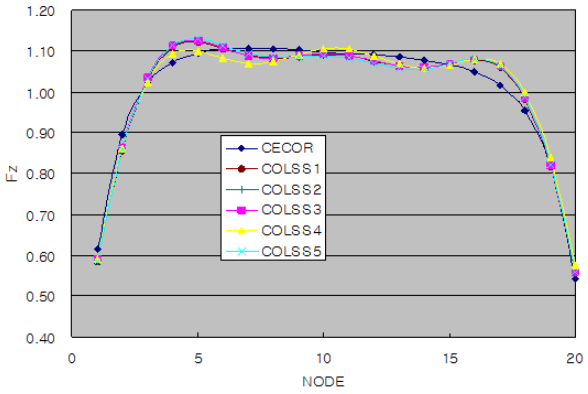


Figure 2 Power Distribution for unit 2

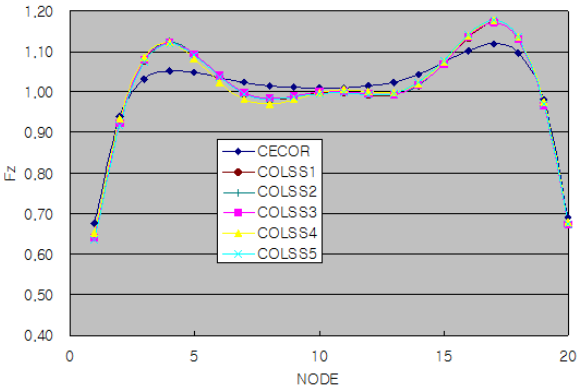


Figure3 Power Distribution for unit 3

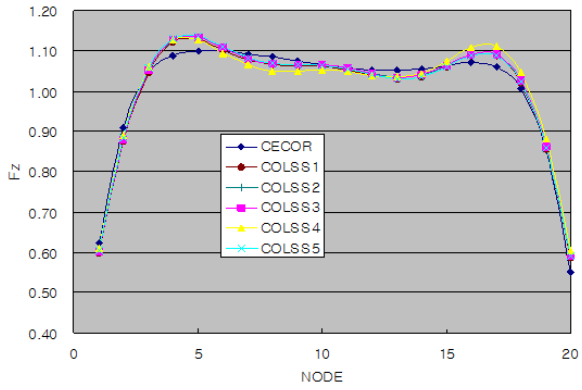
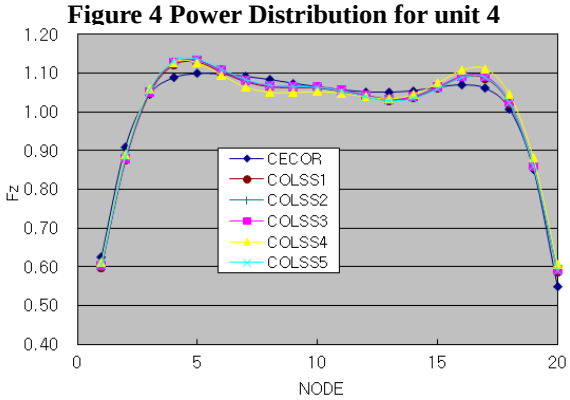


Table 1-4 and Figure 1-4 show that COLSS Power Distribution is more accurate than CPC Power Distribution though inoperable ICIs increase. That is, though 50% ICIs are inoperable, COLSS calculates more accurate power distribution than that of CPC. Therefore, relief of set-point for the number of operable ICIs is reasonable. Based on above methodology and results, the program to relieve set-point for the number of operable ICIs were applied to Hanbit #3, 4, 5, 6 and Hanul #3, 4, 5, 6.

Figure 4 Power Distribution for unit 4



In order to change the set-point, the part design change of Plant Monitoring System (PMS) DB and on-line COLSS program is required. The revision of Plant Monitoring and Annunciator System (PMAS[1]) DB and on-line COLSS program for Shin-Kori #1, 2 and Shin-Wolsong #1, 2 has been completed. They are waiting for an opportunity because the related work should be performed within outage period.

3. Conclusion

KHNP, KEPCONF and KEPCO ENC have proposed the way that COLSS can be operable though operable ICIs exist between 60% ~ 75%. Conservatively, the analysis was performed assuming 50% ICIs are inoperable. Though 50% ICIs are inoperable, the power distribution of COLSS is more accurate than that of CPC. The technology was applied to OPR1000s based on above technical background. Shin-Kori #1, 2 and Shin-Wolsong #1, 2 are waiting for an application. The application of this method will contribute that it makes COLSS operable and transient of nuclear power plant not be induced though above 25% ICIs are inoperable.

Reference

1. KHNP, Shin-Kori #1,2 Improved Technical Specification, 2011
2. KHNP, Hanul #3, 4 Final Safety Analysis Report, 1998
3. KHNP, KEPCO ENC, KEPCONF, Evaluation Report to apply the plan to relieve in-core detector operation limit, 2006

[1] PMAS is Plant Monitoring System and Plant Annunciator System in OPR1000. Actually, two systems are combined by one system (PMAS) since Shin-Kori #1, 2