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A case study for SAM dissatisfaction due to ICI failure in OPR1000

Roh Kyung-ho, Jang Ji-hoon, Jung Won-chae
KHNP, 1312, Yuseong-daero, Yuseong-Gu, Daejeon, Korea, 305-343 (socoban@khnp.co.kr)
*Corresponding author: socoban@khnp.co.kr

1. Introduction

SAM(Shape Anealing Matrix)[1], called ex-core detector calibration constant, is a important addressable constant to calculate the neutron power in reactor core, using the ex-core detector signal. It is detemined and installed into the Core Protection Calculator System (CPCS) at BOC (Beginning of Cycle). Because it is used by EOC (End of Cycle), it is very important to determine the value at BOC. Test should be performed again with other way if SAM didn't meet criteria.

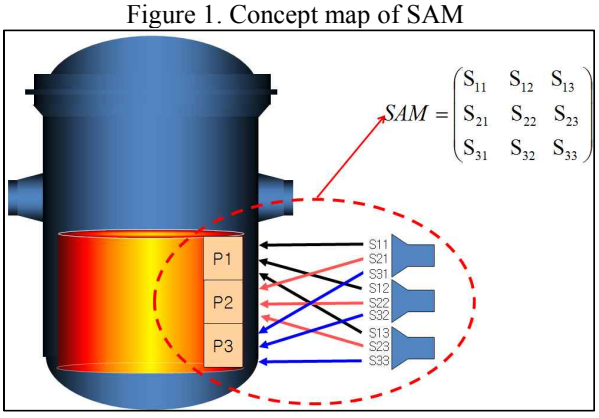
Recently, The case that SAM didn't meet criteria occurred in OPR1000. Therefore, this paper describes test procedure to determine SAM, cause analysis for that case, action result and subsquent action for recurrence prevention.

2. Analysis

2.1 Test procedure

Core Protection Calculator System (CPCS) Calculates the core ASI(Axial Shape Index), DNBR, LPD using the ex-core detector signal. SAM plays a role as constant to consider various power distribution shapes to be able to occur in core. Figure 1. shows the concept of SAM.

Figure 1. Concept map of SAM



It is calculated using acquired data every 30 minutes during ascending the power from 30% to 80% according to Power ascending procedure of OPR1000. Acquired data is called snapshot. Calculated SAM is checked whether meet criteria or not. Criteria are like follows;[3]

① Difference between neutron flux power and thermal power is Within 2% whenever acquiring every snapshot
② Difference between neutron flux power and their average is Within 1.678% whenever acquiring every snapshot
③ Difference between predicted signal and measured signal for top/bottom (middle) detector is Within 6% (4%) whenever acquiring every snapshot
④ Test value is greater than 3 and less than 6
⑤ Standard deviation of differnce between peripheral power using in-core detector and SAM is within 0.5%
⑥ RMS error between axial power distribution using in-core detector and SAM is within 5.5%

When above criteria meet, SAM will be installed into the CPCS as ex-core detector calibration constant.

2.2 Judgement criteria dissatisfaction

Relavant unit violated No. ⑤ criteria. Table 1. shows violation data. Peripheral power error of CPC CH. A was 0.5396% and it exceed 0.5%. However, that of Ch. B/C/D meets criteria. It is not descibed because No. ①, ②, ③, ④ and ⑥ items didn't violated criteria.

Table 1. No. 5 Test Result

Item	criteria	CPC CH.			
		A	B	C	D
Peripheral power error	0.5%	**0.5396**	0.1236	0.1239	0.1190

2.3 Action and Analysis

In order to understand the cuase of No. ⑤ criteria dissatisfaction, KHNP reviewed below items;

- Ex-core detector calibration data
- Computerized code input and output related to core operation variables
- ICI(In-Core Instrumentation) signal

Primarily, it was recognized that something of quadrant related to CH. A have problems through table 1. Therefore, computerized code outputs of CH. A were reviewed intensively. Figure 2. shows the middle peripheral power (Predicted). Figure 3. shows the middle excore detector signal(Measured). Figure 2. shows a sudden change of the prediceted peripheral power at 27th case. However, figure 3. shows a steady change of ex-core detector signal. During taking action (including computerized code outputs and snapshots) to understand the cause, it was recognized that ICI signal is abnormal at 27 snapshots out of total 85 snapshots. ICIs of No. 5 and No. 36 failed. Unfortunately, No. 5 ICI (Axially 3rd detector) of failed ICIs has a major effect as calculating the peripheral power. Figure 4. shows the result of ICI CH. check. ICIs of No. 5 and No. 36 didn't pass the consistency test[1].Because No. 36

ICI has a minor effect as calculating the peripheral power, it isn't described about No. 36 ICI, saperately. Figure 5. shows the detector location and identification in core.

Figure 2. Predicted peripheral power(middle)

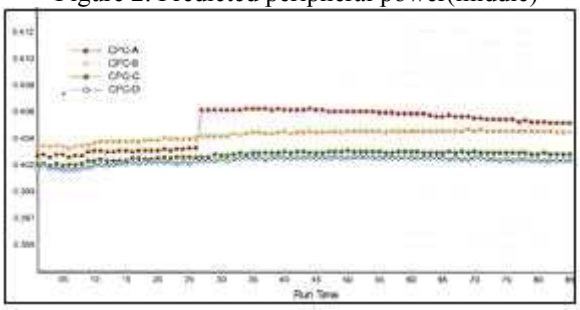


Figure 3. Measured ex-core detector signal (middle)

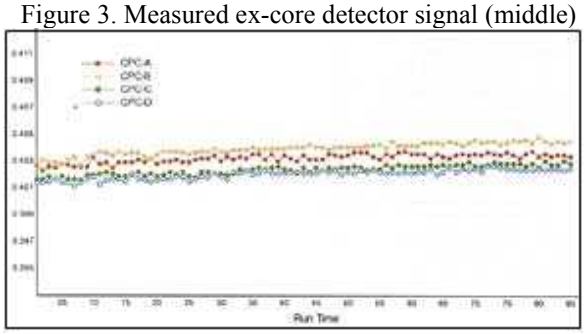
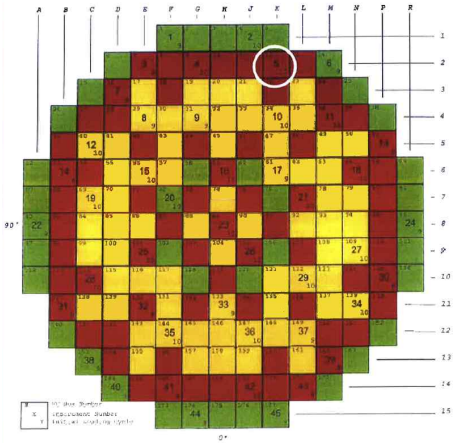


Figure 4. CECOR output for ICI CH. Check[1]

LIST OF CURRENT INSTRUMENT STATUS
(0=GOOD INITIALLY)
(1=SUSPECT, PASSED CONSISTENCY TEST)
(2=FAILED INITIALLY)
(3=FAILED WEDGE TEST)
(4=PASSED CONSISTENCY TEST)
(5=FAILED CONSISTENCY TEST)
NUMBER OF QUANTITIES 225

INST.NO.	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
1	4	1	1	1	1
2	4	4	4	4	1
3	4	4	1	4	4
4	4	1	4	1	4
5	4	4	5	4	4
6	4	4	4	4	4
7	4	4	4	4	4
8	4	4	4	4	4
9	4	1	4	4	4
24	4	4	4	4	4
25	4	4	4	4	4
26	4	4	4	4	4
27	4	4	4	4	4
28	4	1	4	4	4
29	4	4	4	4	4
30	4	4	4	4	4
31	4	4	4	4	4
32	4	4	4	4	4
33	4	4	1	4	4
34	4	4	4	4	4
35	4	4	4	1	4
36	4	4	5	1	4

Figure 5. Core map and ICI location



2.5 Result

Through data analysis, relavant ICI was taken action for "out of scan". This means that the ICI signal isn't used to calculate SAM because ICI fails. After that, SAM was calculated again with excluding the failed ICI signal.

3. Conclusion

A case for SAM dissatisfaction has been analyzed. The problem was ICI signal that has a major effect as calculating peripheral power. Fortunately, there was no problem for producing the electrical power because the cause was understood quickly. This event occurred because there is no procedure that operator checks during physics test whether ICI failed or not. Therefore, test procedure will be improved in order to be able to check the status of ICI for recurrence prevention. Improved items are like follows;

- Action items when test don't meet criteria
- Addition of review step for ICI signal when obtaining snapshots
- Way to deal ICI that don't pass the consistency test.

Reference

1. CE NPSD-103-P, revision 1-P, CECOR 2.0 General Description Method and Algorithms, Aug. 1984.
2. Kyung Ho Roh, Sun Kwan Hong, Solution of ill-posedness Using Constrained Simulated Annealing, Transaction of the KNS Autumn Meeting, Oct. 2008.
3. Core-1008, reactor physics test procedure during power ascending, Jul. 2014.

[1] Consistency Test : Test to compare measured and predicted signal at location of ICI detector. Difference should be within 15%.