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# The Comparison of the Performance by CISAM and CSASAM

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## 1. Introduction

OPR1000 has digitalized Core Protection Calculator (CPC) which calculates DNBR and LPD continuously to generate the reactor trip signals using ex-core detector signal. The reliability of CPC is essential for the safe operation. The CPC calculates 4 channel (A, B, C, D) reactor power independently, which one consist of 3 sub-channel (upper, middle, lower) ex-core detector signals to synthesize the axial power distribution. SAM (Shape Annealing Matrix) is the main mathematical synthesis constants between the real peripheral core power and the ex-core detector signals. So the accuracy of the SAM is very important for the safe and reliable CPC. KHNP-CRI developed the Constrained Simulated Annealing (CSA) method to calculate the SAM in 2008. Until now, CSA method has contributed the reduction of CPC axial power distribution error in the OPR1000 plants. The foreign utility[1] which has used the CISAM (Cycle Independent SAM) method asked KHNP to analyze the data of one Unit. In this paper, the performance between the CSASAM and CISAM will be compared using the unit data.

## 2. Method and Results

The method comparing the performance of the CSASAM and the CISAM is as follows;

a. Calculate the SAM using the data of a foreign utility Unit with the CSA and CI method
b. Using the calculated SAM (both CSA and CI), Calculate the CPC axial power distribution RMS error over the applicable cycle
c. Compare CPC axial power distribution RMS error of the CSA method and the CI method

### 2.1 CSA method [1]

#### 2.1.1 Constraint

SAM is unique matrix which has the physical and mathematical meaning itself between the peripheral core power and the ex-core detector signals. By using the inverse SAM, we can make two constraints to solve the equation.

$$\begin{pmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{pmatrix}^{-1} = \begin{pmatrix} w_{11} & w_{12} & w_{13} \\ w_{21} & w_{22} & w_{23} \\ w_{31} & w_{32} & w_{33} \end{pmatrix} \quad (1)$$

$$\begin{aligned} W_{11} &> W_{12} > W_{13} \\ W_{21} &< W_{22} > W_{23} \\ W_{31} &< W_{32} < W_{33} \end{aligned} \quad (2)$$

At the eq. (1), all the inverse SAM elements must be positive value. Because physically every elements which stand for the neutron detect probability should be positive no matter where they are located

#### 2.1.2 Simulated Annealing

To calculate the SAM, KHNP used Simulated Annealing method as numerical method which is statistical numerical optimization. It is an easy method to apply to constraint. To develop the advanced SAM solving algorithms, we test a new optimization algorithm, simulated annealing with constraints. Consequently we confirm that the simulated annealing method can find not only the global optimum value, it is also less likely to fail on difficult functions because it is a very robust algorithm.

#### 2.1.3 A case of OPR1000 CPC RMS error

Figure1 shows a case of OPR1000 CPC RMS error. RMS error exceeded 10% before CSA method was applied. It means that CSA method is contributing the reduction of RMS error.

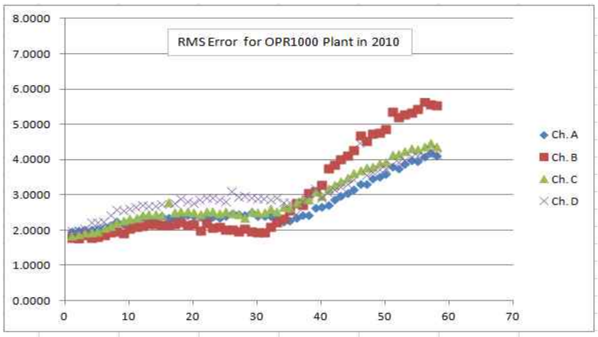


Figure1. CPC axial power distribution RMS error of OPR1000 plant

### 2.2 Cycle Independent Method [2]

The concept of the CISAM can be supported by analytical considerations, by simulation and by analysis of historical data. The proposed methodology to determine and evaluate the CISAM will deviate from the current methodology of SAM/BPPCC measurement in minor ways. They are follows;

a. In the calculation of the CISAM from the measurements the core average power integrals will be used instead of the peripheral power integrals

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1 According to the latest information, it plans to replace the ex-core detector.

b. The input data for CISAM calculation will be smoothed unless otherwise directed via user input
c. The input data for CISAM calculation shall be from a mid-cycle or late-cycle FPA or from an axial power oscillation with a minimum ASI variation of ±0.075

2.3 Results

2.3.1 Comparison of SAM by CSA and CI method

Table1 shows the SAM using CI method. From SAM elemental viewpoint, it seems to be non-physical in the Ch. B. and Ch. C.

Table1. SAM using CI method for a foreign utility Unit

| | | | | | |
|---|---|---|---|---|---|
| CHANNEL A | | | CHANNEL B | | |
| 3.9636 | -0.4447 | -0.3897 | 3.7040 | 0.0543 | -0.6401 |
| -0.5561 | 3.9183 | -0.5145 | -0.5944 | 3.7212 | -0.2633 |
| -0.4075 | -0.4736 | 3.9042 | -0.1096 | -0.7755 | 3.9034 |
| CHANNEL C | | | CHANNEL D | | |
| 3.3966 | 0.4375 | -0.7729 | 3.7310 | -0.0535 | -0.5928 |
| -0.2071 | 3.2463 | -0.0866 | -0.7296 | 4.0633 | -0.5375 |
| -0.1895 | -0.6839 | 3.8595 | -0.0014 | -1.0098 | 4.1303 |

Table2 shows the SAM using CSA method. From SAM elemental viewpoint, it seems to be physical

Table2. SAM using CSA method for a foreign utility Unit

| | | | | | |
|---|---|---|---|---|---|
| CHANNEL A | | | CHANNEL B | | |
| 4.5537 | -1.3804 | 0.1148 | 4.3132 | -0.8635 | -0.1698 |
| -1.1453 | 4.8366 | -0.9978 | -0.5430 | 3.6516 | -0.2332 |
| -0.3538 | -0.6524 | 4.0650 | -0.5169 | -0.1762 | 3.6071 |
| CHANNEL C | | | CHANNEL D | | |
| 3.8719 | -0.2501 | -0.4374 | 4.5633 | -1.3588 | 0.1198 |
| -0.9605 | 4.4336 | -0.7359 | -1.0989 | 4.6339 | -0.8425 |
| -0.4939 | -0.2015 | 3.5938 | -0.5228 | -0.1716 | 3.6592 |

2.3.2 Comparison of CPC axial power distribution error by CSA and CI method

Figure2 shows the CPC axial power distribution error by CI method over the applicable cycle.

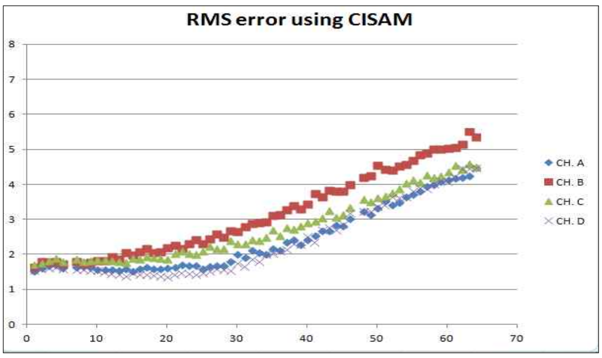


Figure2. CPC axial power distribution RMS error using CISAM method

Figure3 shows the CPC axial power distribution error by CSA method over the applicable cycle.

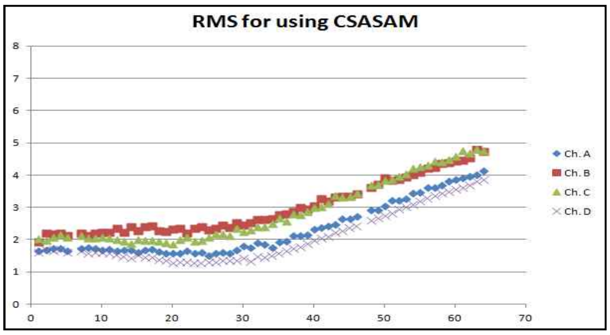


Figure3. CPC axial power distribution RMS error using CSASAM method

When Fig.2 and Fig.3 are compared, the performance using CSASAM method seems to be better. However, SAMs for both methods are available to the CPC because the limit for RMS error is 8%.

3. Conclusion

KHNP-CRI calculated the SAM using CSA method for the unit and compared the RMS error by CSASAM and CISAM. In conclusion, the CSA method seems to be better than CI method according to figure2 and figure3. Because CI method needs to have the historical data of ex-core detector signal over multi-cycle to calculate the SAM, it is not useful for new ex-core detector. Therefore, the CSA method will be useful for ex-core detector replacement.

Reference

1. Kyung Ho Roh, Sun Kwan Hong, Solution of ill-posedness Using Constrained Simulated Annealing, Transaction of the KNS Autumn Meeting, Oct. 2008
2. CE NPSD-984-P, Cycle Independent Shape Annealing Matrix Methodology prepared for the C-E Owners Group, Sep. 1995.
3. Sang Rae Moon*, Sung Tae Yang, Ki Young Kim, Verification of Advanced SAM Using Constrained Simulated Annealing, Transaction of the KNS Autumn Meeting, Oct. 2008