A case study of inaccuracy of advanced SAM application in the OPR1000

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1. Introduction

KHNP has developed a constrained simulated annealing method to account for the weakness of the least square method when using the SAM[i] calculation for applications related to the OPR1000 [1].

The SAM is generated and installed once at the beginning of each cycle. Thus, the accuracy of ASI[ii] simulation by CPC [iii] is wholly dependent on the accuracy of the SAM constants. As the depletion proceeds, the deviation of the CPC axial power shape increases. When noise is included, the measurement data frequently exceeds the limit (8%) of the CPC ASI deviation. Therefore, KHNP has developed a constrained simulated annealing method [2] to filter the noise from the measurement data and give the SAM a physical meaning. These two objectives form the core of the developed method. The least square method makes it difficult to implement the algorithm for filtering the noise. Thus, a mathematical method that has been used and verified in a variety of fields was adopted for the simulated annealing .

In this paper, the relationship between the SAM and CPC axial power shape deviation is analyzed [3], based on results showing that EOC[iv] CPC axial power shape deviation has approached the limit (8%) in the OPR1000 when the simulated annealing method was applied .

2. Analysis of the CPC axial power shape deviation

It is assumed that the outer top/middle/bottom power in the core is related to the top/middle /bottom detector signal and the SAM is calculated through Eq. (1)

$$\begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix} \begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix} \tag{1}$$

Eq. (2) is the basic equation of the least square and Eq. (3) is the cost function, which is the basic equation, of the simulated annealing.

$$\begin{bmatrix} S_{i1} \\ S_{i2} \\ S_{i3} \end{bmatrix} = (D^T D)^{-1} D^T P \tag{2}$$

$$E(s_i) = [(D^T D)s_i - D^T p]^2 \tag{3}$$

The least square method must be differentiable whereas the simulated annealing method does not. In other words, the simulated annealing method calculates the SAM that cost function is minimized through a number of iterations. Although the calculated SAM is not meaningful, the Inverse SAM is meaningful for the physical analysis. Because the inverse SAM is the weighting factor for the impact of the outer power on the ex-core detector, the sum of the element of the inverse SAM matrix is 1. When using, the least square method, it must be differentiable, but with the simulated annealing, the result does not need to differentiable and thus may vary from 1. However, it is not yet known whether this result is a good reflection of the core characteristic.

The Figure 1&2 show that the CPC axial power shape deviation has approached the limit (8%). The CPC axial power shape deviation is calculated by Eq. (4). This example shows that the simulated annealing method has an impact somewhat related to the noise.

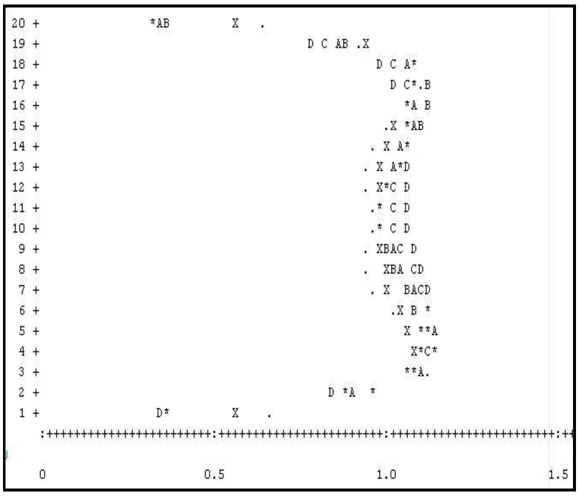

Figure1. CPC axial power shape deviation (unit 1)

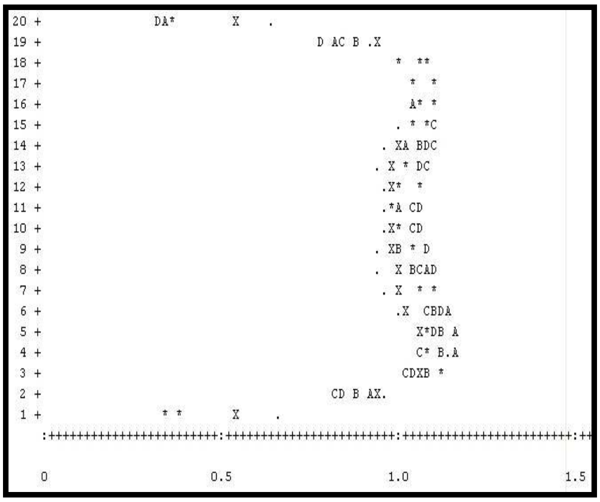

Figure2. CPC axial power shape deviation (unit 2)

$$Dev. = \sqrt{\sum_{i=3}^{18}\left[\frac{F_z(i)^{CPC} - F_z(i)^{CECOR}}{F_z(i)^{CECOR}} \times 100\right]^2 / 16} \quad (4)$$

3. Conclusion and recommendation

Analysis of the EOC CPC axial power shape deviation was implemented, based on data that the deviation has approached the limit (8%). In Figure 1 and 2, the CPC axial power shape deviation does not exceed the limit, but if the burn-up increases, the limits of many OPR1000s will be exceeded.

Therefore, an upgrade of the constrained simulated annealing method will have to be considered in order to make SAM free from the noise through the additive constraint, to modify the number of iterations and so on.

REFERENCES

[1] Kyung-Ho Roh and Sun-Kwan Hong, Development of Advanced SAM using Constrained Simulated Annealing, Tansactions of the KNS autumn meeting, Oct. 2008.

[2] Ho-Cheol Shin, Moon-Ghu Park, Sung-Tae Yang, Kyung-Ho Roh, Sang-Rae Moon and Sun-Kwan Hong, Locally Optimal Solution of Robust Excore-Detector Response using Constrained Simulated Annealing, Nuclear Engineering and Design, Vol.239, Issue 1, Jan. 2009, Page 51-57

[3] Sang-Rae Moon, Sung-Tae Yang and Ki-Young Kim, Verification of Advanced SAM using constrained simulated annealing, Tansactions of the KNS autumn meeting, Oct. 2008.

[i] SAM : Shape Annealing Matrix
[ii] ASI : Axial Shape Index
[iii] CPC : Core Protection Calculator
[iv] EOC : End Of Cycle