Optimization for the computerized code calculating SAM

Roh Kyung-Ho *, Yang Sung-Tae, Son Jin-Won
Korea Hydro & Nuclear Power Co., Ltd. 1312, Yuseong-daero, Yuseong-Gu, Daejeon, Korea, 305-343
socoban@khnp.co.kr

1. Introduction

In a previous paper "A case study of inaccuracy of advanced SAM application in the OPR1000" **[1]** (submitted at the KNS spring meeting on May 27, 2011), KHNP addressed the inaccuracy of the Shape Annealing Matrix (SAM) using the Constrained Simulated Annealing Method (CSAM). Because the data obtained by the ex-core detector is based on the assumption that the signal is linear at each power level, the SAM will inherently be inaccurate if the signal includes a little noise. To address this situation, KHNP tried to enhance the reliability and operational margin of OPR1000 by optimizing the computerized code used in the SAM calculation. In this paper, KHNP selected two factors which affect the SAM calculation in the CSAM algorithm and reflected them in the computerized code. KHNP then re-calculated the SAM using the beginning of cycle (BOC) data, which CPC axial power shape deviation had increased in the End of Cycle (EOC), and simulated the CPC axial power shape deviation.

2. Optimization of CEFAST calculating SAM

2.1 Simulated Annealing Method used in the CEFAST[i]

Equation (1) is the cost function of the Simulated Annealing Method. The S_i value is the solution when the $E(S_i)$ value is minimum **[2].**

$$E(s_i) = [(D^T D)s_i - D^T p]^2 \qquad (1)$$

Where, D: detector signal
P: Peripheral Power

Simulated Annealing (SA) is a random-search technique which exploits an analogy between the way in which a metal cools and freezes into a minimum energy crystalline structure (the annealing process) and the search for a minimum in a more general system. SA forms the basis of an optimization technique for combinatorial and other problems. The SA algorithm is performed for the each coordinate axis by the random walk. The above method enables the solution to access the global minima from the local minima. SA can be determined by the following equation if it is formulated to solve the non-linear optimization problem with the constrained range.

$$Min\ E(x)\ \ Satisfying\ \ g_i(x) \le b_i \quad i \in M \qquad (2)$$

Where, E(x): cost function
b_i: the upper and lower limit of variable x

SA can find the solution at the random point within the concerned range. Let this point be X_{old} and the cost function of this time be E_{old}. After that, run the random walk. Let the new point be X_{new} and the cost function of this time be E_{new}. Here, we can define the difference between via:

$$\Delta E = E(x_{new}) - E(x_{old}) \qquad (3)$$

Also, using ΔE, we can define the probability P as:

$$P = \exp\left(-\frac{\Delta E}{k_b T}\right) \qquad (4)$$

where, k_b : Boltzmann constant
T : Temperature

The SA algorithm compares P with r, which is a random number between 0 and 1. According to whether P is larger or smaller than r, X_{new} is received or not. That is, if P is larger than r, X_{new} is considered to be the new solution. T is the control variable labeled as temperature. Like equation (4), P can be controlled through T. The larger the value of T, the larger the value of P, where P represents the probability to be received as the starting point. If the starting point is decided, SA continues to renew the solution in the same way.

2.2 Sensitivity analysis for impacting factors

Therefore, the factors affecting the solution were considered and a sensitivity analysis was performed. T and random walk are used as iteration numbers, while b_i is the upper and lower limit to search the solution. KHNP reasonably modified the factors and re-calculated SAM. Also, the effect that the re-calculated SAM had on EOC CPC axial power shape deviation was evaluated, and the results are as follows:

Case	Impacting factor*		CPC axial power shape deviation**			
			Ch. A	Ch. B	Ch. C	Ch. D
1	Iteration number	150 times	7.5345	7.6246	7.5571	6.9317
2		175 times	7.7655	5.9939	8.5094	9.1105
3		225 times	8.9414	6.2038	6.9244	8.3256

[i] The Computerized code calculating SAM

4		245 times	7.7640	5.9939	8.8350	9.1105
5	upper and lower limit	±100	7.1646	6.2407	6.9939	7.2700
6		±10	6.7621	5.3482	5.9536	6.2307

Table 1. CPC axial power shape deviation according to the impacting factors

* Original iteration number before modification: 125 times

* Original upper and lower limit before modification: ±1,000

** Original CPC axial power shape deviation before modification

→ Ch. A : 8.0421%, Ch. B : 6.2898, Ch. C : 6.1549, Ch. D : 8.9441

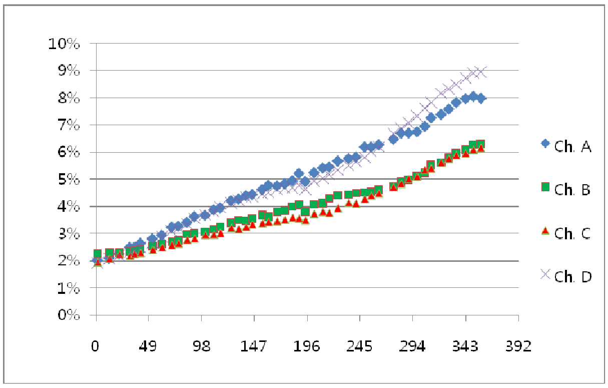

Figure1. CPC axial power shape deviation trend before modification

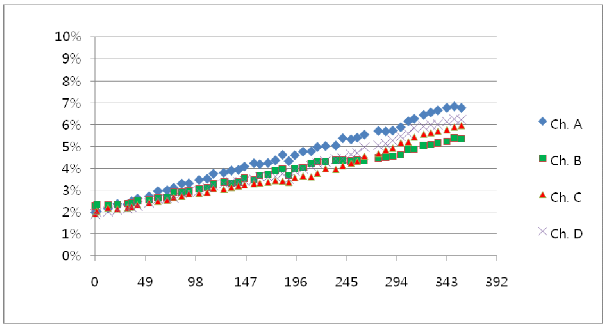

Figure 2. CPC axial power shape deviation trend after modification.

As shown in Table 1 and Figures 1 and 2, case 6 has the lowest deviation. On the other hand, the result of the case with the modified iteration number is inconsistent and has little reducing effect. Namely, the case with the upper and lower limit modified to ±10 is most effective. Finally, the CPC axial power shape deviation is reduced by about 15% by modifying the upper and lower limit.

3. Conclusion

After previously raising the issue of the inaccuracy of SAM using CSAM, KHNP has attempted to solve this problem in the CSAM algorithm. In the point of the CSAM algorithm, two impacting factors were drawn and a sensitivity analysis for those factors was performed. The analysis results show that modifying the upper and lower limit produces the largest effect, and that the effect for CPC axial power shape deviation was about 15%.

REFERENCES

[1] Roh, Kyung- Ho, Yang, Sung-Tae, Jung, Ji-Eun, "A case study of inaccuracy of advanced SAM application in the OPR1000", Transactions of the KNS spring meeting, May 26-27, 2011

[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", NED, Vol. 239, Issue 1, Jan. 2009, Page 51-57