Elimination of Noise Effect in Snapshot Data for Accurate CPC SAM Calculation

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1. Introduction

The OPR/APR power plant has a Core Protection Calculator (CPC) system. CPC monitors LPD and DNBR, the main operating variables of the core, and provides a Plant Protection System (PPS) with a signal to allow reactor shutdown to occur if it exceeds the set point in transient or abnormal situations.

When calculating DNBR and LPD, power by location in the height direction of nuclear fuel is important, and CPC calculates the axial power distribution using ex-core detector information that acquires neutron information leaked out of the reactor and uses this information to calculate DNBR and LPD.

As the phenomenon in the core is calculated using neutron information leaked out of the reactor, the use of Ex-core instrument information is more uncertain than calculated using In-core instrument information.

Therefore, the CPC axial power distribution using ex-core detector information is operated by imposing a penalty factor on CPC if the error increases by more than 8% compared to the CPC power distribution using in-core information on a weekly basis.

The CPC axial power distribution is calculated using the signal of upper, middle, and lower detector installed in the outside of the reactor, and the shape annealing matrix (SAM) is calculated at the beginning of the cycle and input into the CPC in a variable constant.

SAM compares the power of the in-core and ex-core and corrects the ex-core signal, and the calculation formula is as follows.

$$Pi = S * Di = Pe \text{ (Ex-core Power)}$$

Where, Pi: In-core Power, D: Ex-core Signal
S: Shape Annealing Matrix
Pe: Ex-core Power

That is, S that causes the error between Pi and Pe to be minimized becomes the optimal value of SAM. Conventionally the least square is used for calculation of S. Currently, constrained simulated annealing method is being used[1].

As mentioned earlier, SAM is calculated using the snapshot data acquired among the power increase (30-80%) at the beginning of the cycle, and all of the acquired data is used without addition or subtraction.

Determining the initial SAM value is very important because once determined SAM is installed in CPC and used until the end of the cycle.

Therefore, if data with a noise signal is used, errors in the SAM value may occur, but on the other hand, it is very difficult to determine whether the acquired data is a noise signal.

Accordingly, this paper assumed that the data used to calculate SAM and the data whose power and axial power distribution values move in the opposite trend were mixed with noise signals, removed the data, calculated SAM, and reviewed the integrity of the SAM value calculated at this time.

2. Methods and Results

This section compares and reviews two kinds of SAMs with all measured snapshots and partial data removed.

2.1 The selection of data to be removed

Excluding actual measured data is difficult for regulatory body and utility to determine due to the possibility of data error because there is no standard. On the other hand, applying data containing noise to the core protection system also does not seem desirable in terms of safety. In this case, this paper was written under the assumption that it would be reasonable to remove data with some standards. As mentioned earlier, since there is no way to accurately identify noise signals among snapshot data, this paper assumes that the case in which the change in power and ASI has an inconsistent trend is an example of adding noise signals. One case of OPR nuclear power plant operation in the past was selected and a data set assumed to be a noise signal was selected. Table 1 and Figure 1 below show some of the data and trends of the power and ASI of snapshots acquired during the power ascension from 30% to 80% of the OPR nuclear power plant. In the table, Snapshot 17, 19, and 38 were assumed to be data with noise signals because of data showing opposite trends in power and ASI.

Table 1. PWR vs ASI data

Snapshot #	Power	ASI
1	28.61	-0.1167
2	30.19	-0.1124
3	29.98	-0.1133
~		
16	40.82	-0.093
17	**41.2**	**-0.0934**
18	42	-0.0913
19	**42.17**	**-0.0914**
20	43.08	-0.0898
~		
37	56.24	-0.0726
38	**56.76**	**-0.0729**
~		
72	78.75	-0.0363

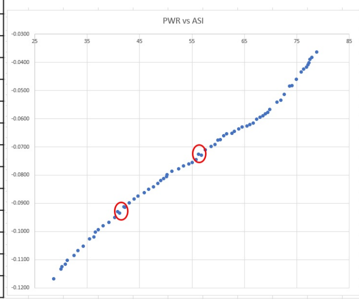


Figure 1. PWR vs ASI trend

2.2 Case 1 (SAM value, all data used)

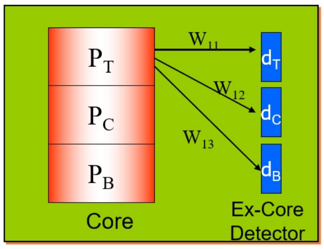
```
CPC CHANNEL A                    71 DATA SETS ANALYZED
-------------
    SAM MATRIX                  4.6998     -0.7638     -1.1129
                               -0.6582      4.1680     -1.1190
                               -1.1939     -0.2000      5.0921  TEST VALUE =     4.0636
    INVERSE SAM MATRIX          0.2348      0.0460      0.0614
                                0.0524      0.2527      0.0670
                                0.0571      0.0207      0.2134

CPC CHANNEL B                    71 DATA SETS ANALYZED
-------------
    SAM MATRIX                  4.4697     -0.5959     -1.1034
                               -0.7995      4.1716     -0.9134
                               -0.4495     -0.8692      5.2138  TEST VALUE =     4.0175
    INVERSE SAM MATRIX          0.2379      0.0462      0.0584
                                0.0520      0.2589      0.0564
                                0.0292      0.0471      0.2062

CPC CHANNEL C                    71 DATA SETS ANALYZED
-------------
    SAM MATRIX                  4.2749     -0.0780     -1.6361
                               -0.9130      4.1229     -0.8591
                               -0.2576     -1.1762      5.5834  TEST VALUE =     4.0249
    INVERSE SAM MATRIX          0.2441      0.0262      0.0755
                                0.0590      0.2600      0.0573
                                0.0237      0.0560      0.1947

CPC CHANNEL D                    71 DATA SETS ANALYZED
-------------
    SAM MATRIX                  4.5575     -0.6285     -1.1441
                               -0.1876      3.3836     -0.4096
                               -0.4460     -0.8692      5.1895  TEST VALUE =     3.8810
    INVERSE SAM MATRIX          0.2271      0.0562      0.0545
                                0.0153      0.3054      0.0275
                                0.0221      0.0560      0.2020
```

2.3 Case 2 (SAM value, selected data removed)

```
CPC CHANNEL A                    68 DATA SETS ANALYZED
-------------
    SAM MATRIX                  4.1728     -0.0408     -1.6216
                               -0.5902      4.0487     -1.0111
                               -1.0739     -0.3367      5.1611  TEST VALUE =     4.0021
    INVERSE SAM MATRIX          0.2627      0.0097      0.0844
                                0.0528      0.2530      0.0662
                                0.0581      0.0185      0.2156

CPC CHANNEL B                    68 DATA SETS ANALYZED
-------------
    SAM MATRIX                  4.6963     -0.8898     -0.9148
                               -0.7498      4.0983     -0.8570
                               -0.6221     -0.6312      5.0459  TEST VALUE =     4.0144
    INVERSE SAM MATRIX          0.2289      0.0576      0.0513
                                0.0491      0.2629      0.0535
                                0.0344      0.0400      0.2112

CPC CHANNEL C                    68 DATA SETS ANALYZED
-------------
    SAM MATRIX                  4.2159     -0.0021     -1.6886
                               -0.9198      4.1211     -0.8476
                               -0.5894     -0.7829      5.3458  TEST VALUE =     4.0229
    INVERSE SAM MATRIX          0.2521      0.0157      0.0821
                                0.0639      0.2542      0.0605
                                0.0372      0.0390      0.2050

CPC CHANNEL D                    68 DATA SETS ANALYZED
-------------
    SAM MATRIX                  4.2341     -0.2781     -1.3008
                               -0.7542      4.0861     -0.8313
                               -0.3594     -0.9765      5.2540  TEST VALUE =     3.9759
    INVERSE SAM MATRIX          0.2477      0.0327      0.0665
                                0.0511      0.2611      0.0540
                                0.0264      0.0508      0.2049
```

2.4 SAM value Analysis

The SAM value is a correlation constant that minimizes the power difference between the in-core and ex-core measuring instruments, and it is difficult to explain the physical meaning of each element. Accordingly, it is evaluated whether the SAM value is satisfied by checking how much the Test Value is. However, since each element of INVERSE SAM has the meaning of the weight of the neutron leaking from the core to the upper/middle/lower detector, it is possible to evaluate the satisfaction of SAM with the results of INVERSE SAM. The magnitude of each element of INVERSE SAM is as follows.



$$w_{11} > w_{12} > w_{13}$$
$$w_{21} < w_{22} > w_{23}$$
$$w_{31} < w_{32} < w_{33}$$

Figure 2. The characteristic of INVERSE SAM

In general, the Test Value of the SAM value is estimated to be around 4.0 in the case of OPR nuclear power plants [2]. In the case of the analysis above, the data assumed as a noise signal was removed and calculated, resulting in a closer Test Value to 4.0. However, considering the physical meaning of INVERSE SAM, Case 2 did not obtain a better result.

3. Conclusions

Since it is difficult to check the presence or absence of a noise signal when acquiring data during the power ascension to calculate SAM, the SAM was calculated assuming that the noise signal came in when trend of power and ASI was opposite. That is, the data of this time were removed. The calculation result confirmed that the theoretically known value in terms of the Test Value was closer, but the value of each element of INVERSE SAM, which has a physical meaning, did not show a meaningful result. In the future, it seems to need to verify the validity of the assumption in this case by confirming how much the error in the CPC power distribution increases by the end of the cycle by the new SAM value.

REFERENCES

[1] Ho-Cheol Shin et.al., Locally Optimal Solution of Robust Ex-core Detector Response Using Constrained Simulated Annealing, Nuclear Engineering and Design, 239 (2009)
[2] Sang Rae Moon, Sung Tae Yang, Ki Young Kim, Verification of Advanced SAM Using Constrained Simulated Annealing, 2008 KNS Autumn Meeting.