An Automated Calculation Program for the Axial Xenon Stability Index

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1. Introduction

There are several fission products that have extremely high thermal neutron absorption cross sections which can exert a strong influence on reactivity of a nuclear reactor. Among them, ^{135}Xe is the most important one because of its enormous thermal neutron absorption cross section (2.7×10^6 b) and relatively high production yield. Besides, the relation between ^{135}Xe fission production yield and neutron flux change creates a local change in the nuclear reactor and induces a spatial oscillation of power in the reactor core [1]. To indicate the tendency of amplitude of this oscillation, the value of stability index [2] is used. The positive value of stability index shows that nuclear reactor is unstable, and negative value of stability index shows that nuclear reactor is stable as the oscillation continues. For the stability analysis of a nuclear reactor, this stability index is important and, recently, it has become more important in the use of burnable absorber axial cutback. This paper presents an automated calculational program for the stability index.

2. Theory and Equations

The parameter used in the xenon induced power oscillation stability analysis to control the xenon induced power oscillation is the stability index.

The stability index, b, is defined as the natural exponent which describes the growing or decaying of amplitude in the following equation:

$$ASI(t) = ASI_0 \cdot \exp(bt) \cdot \sin\left(\frac{2\pi t}{T} + t_0\right) + ESI, \tag{1}$$

where ASI_0 is the amplitude of oscillation component of axial shape index, b is stability index, T is period, t_0 is a phase shift, and ESI is the equilibrium shape index, and axial shape index (ASI) is defined below:

$$ASI = (P_B - P_T)/(P_B + P_T), \tag{2}$$

where P_B and P_T are the power in the bottom and top half of the core.

To obtain b from Eq. (1), other two parameters, ASI_1 and ASI_2 are needed. ASI_1 and ASI_2 are defined as the first and second local maximum value of ASI (t), respectively (ASI_1 = ASI (t_1), ASI_2 = ASI (t_2)), and described in Fig. 1.

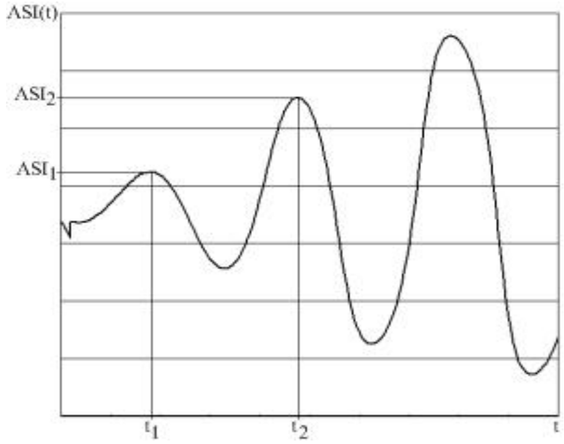

Fig. 1. Definitions of ASI_1 and ASI_2.

Using these two parameters and Eq. (1), T and t_0 can be obtained directly from the sampled data, and ASI_0 and b are expressed as functions of ESI. Therefore, T and t_0 are defined as,

$$T = t_2 - t_1, \tag{3}$$

$$t_0 = \frac{-2\pi(t_1 - T)}{T}. \tag{4}$$

and by substituting Eq. (3) and Eq. (4) to Eq. (1), ASI_0 and b are obtained as,

$$ASI_0 = \frac{ASI_1 - ESI}{\sin(2\pi t_1/T + t_0)\cdot\exp(bt_1)}, \tag{5}$$

$$b = \frac{1}{T}\ln\left(\frac{ASI_2 - ESI}{ASI_1 - ESI}\right). \tag{6}$$

The least squares method is used to find the stability index. In Eq. (1), every parameter can be obtained, if the value of ESI is given. Therefore, the axial shape index according to the time can be calculated by various values of ESI. The whole algorithm is shown in Fig. 2.

3. Numerical Results

The outputs of this program for several problems show quite good results. This paper presents results for the Ulchin Unit 6 Cycle 4 problem. The five parameters shown in Eq. (1) and the sum of squared residuals after 10 hours are listed in Table I. The calculated ASI and the actual ASI from the sampled data for BOC and EOC are shown in Fig. 3 and Fig. 4, respectively.

Table I: Result for U6C4

	BOC	EOC
ESI	-0.053725	0.002525
T	33.50	30
t_0	-1.61687	-2.40733
ASI_0	0.0110443	0.251494
b	**-0.0223357**	**0.0219277**
$RMS_{10..}$	0.00036	0.26299

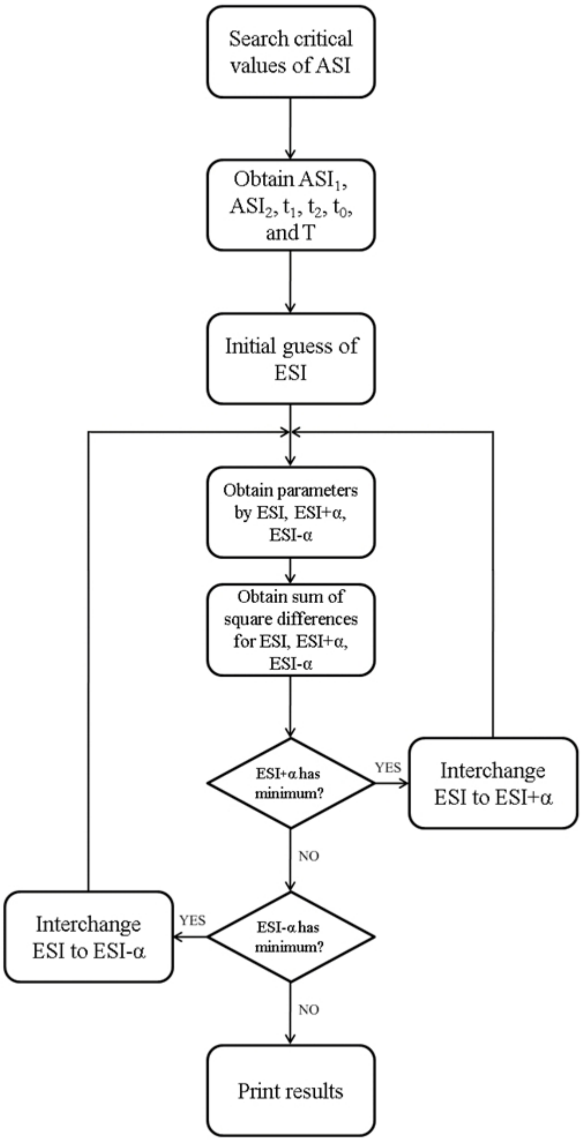

Fig. 2. A flow chart of the automated computer program of calculating xenon induced power oscillation stability index.

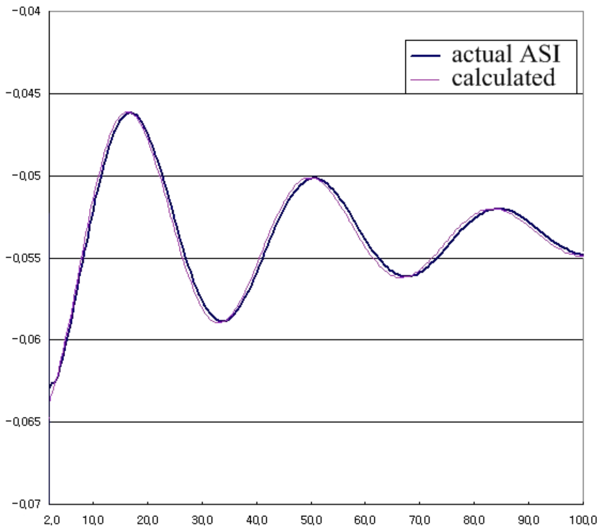

Fig. 3. ASI as a function of time for U6C4 BOC.

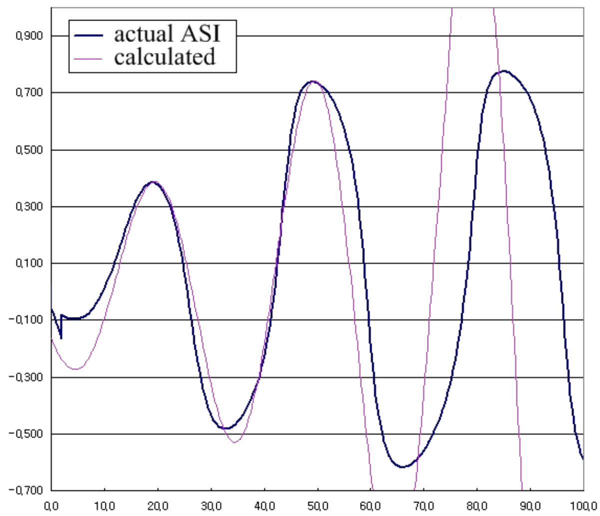

Fig. 4. ASI as a function of time for U6C4 EOC.

4. Conclusions

The task of obtaining the stability index is important in operation of a nuclear power reactor. However, it has been calculated manually in reload core design. This paper reports a recent work on development of an automated computer program and it is expected to be useful for safe operation of power reactors.

REFERENCES

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