IMPLEMENTATION OF THE APPROXIMATED MODEL AS AN AUTOMATED CONTROL SYSTEM OF THE GENERATION II REACTOR ENERGY RELEASE

Vataman Viktoriia Ph.D
Odessa Polytechnic State University, Ukraine

Zhanko Kristina Ph.D
Odessa Polytechnic State University, Ukraine

Summary. Due to the complexity of compensating for reactivity under internal and external disturbances, it is very difficult to maneuver the power output of a nuclear reactor. Moreover, the process parameters calculated as a result of power changes cannot be used in operational automated control systems due to their complexity using physical and mathematical models. An approximation model of the processes occurring in a nuclear reactor in the form of a transfer function was proposed. Integrated into the control system, the approximation model makes it possible to compensate for xenon oscillations and regulate the quantitative measure of nuclear reactor stability.

Key words: energy maneuvering, transfer function, approximation model, reactivity.

An approximation model is proposed to improve the measured and calculated subsystems that are part of the control system for internal processes of a nuclear reactor. [1]. Such subsystems will be able to compensate for changes in nuclear reactor reactivity caused by xenon oscillations during the transition of the core of generation II reactors from one power level to another. Basic physical and mathematical models of nuclear power equipment cannot be integrated for real-time operation. This type of models can be described as "control objectphysical". Since they are nonlinear and cannot quickly calculate the necessary technological parameters for the productive operation of the automated control system of a nuclear power plant [2]. In this case, the operator uses nomograms and manually controls the nuclear power plant [3]. The nomograms themselves are built using previously calculated solutions based on the "control objectphysical" model.

Numerous calculations were carried out for varying the reactance when the capacity was increased to 3000 MW (Fig. 1) and when the capacity was reduced to
the minimum permissible power value (Fig. 2). Fig. 1 and Fig. 2 show step changes in capacity of 25%, 50%, 75%, 100% (750 MW, 1500 MW, 2250 MW, 3000 MW).

Fig. 1. Variation of reactivity at a stepwise increase in load from the specified value to the maximum value of reactor power (up to 3000 MW).

To adjust the controllers of the automated control system, linear differential models were used based on the results of numerical calculations, which was called "control object approximation". This model is built so that the results of calculations based on the two models coincide as much as possible within a certain range of changes in the initial data. Since the "control object approximation" model is linear, it adequately indicates the dependencies used to set up the automated control system's regulators. In our case, the results of the calculations vary depending on the time and the value of the step change in nuclear reactor power [4]. In order to perform the approximation, several conversion steps are required. Schematically, the conversion steps are shown in (Fig. 3).
At the 1st step, each curve (Fig. 1 and Fig. 2) is approximated by one argument. At the initial moment of time, each graph (Fig. 1 and Fig. 2) has \( t=0 \) and reactivity equal to zero \( \rho(0) = 0 \). The polynomial is chosen as an approximating function and has the following form:

\[
    f_j(t) = \sum_{i=1}^{n} c_{i,j} t^i
\]  

(1)

where:

- \( n \) - number of polynomial terms

At the 2nd step, the transfer function of the approximating model of each process is determined (Fig. 1 and Fig. 2). Then, applying the Laplace transform to the approximated polynomial (1), we obtain:

\[
    L\{f_j(t)\} = L\{\sum_{i=1}^{n} c_{i,j} t^i\} = \left[ \sum_{i=1}^{n} c_{i,j} \left( \frac{1}{p} \right)^{i+1} \right] = \left[ \frac{1}{p} \right] \sum_{i=1}^{n} c_{i,j} \left[ \left( \frac{1}{p} \right)^{i+1} \right]
\]  

(2)

where:

- \( i \) - an index indicating the terms of the approximating polynomial for one graph,
- \( j \) - an index indicating different graphs.

Expression (2) is an approximating solution in a spatial representation. Then, applying the Pade approximation, taking into account the second factor of (2) under certain transformations, we obtain:

\[
    \left( \frac{1}{p} \right)^2 \frac{L}{M} = \left[ \frac{\delta_0}{\eta_0} \right] \frac{p^{-M-1} + \frac{\delta_1}{\eta_1} p^{-M-1} \cdot \frac{\delta_2}{\eta_2} p^{-M-1} + \ldots + \frac{\delta_{M-1}}{\eta_{M-1}} p^{-M-1} \cdot \frac{\delta_0}{\eta_0}}{1 + \frac{\delta_0}{\eta_0} p^{-M-1} + \frac{\delta_1}{\eta_1} p^{-M-1} \cdot \frac{\delta_2}{\eta_2} p^{-M-1} + \ldots + \frac{\delta_{M-1}}{\eta_{M-1}} p^{-M-1}} \cdot \frac{\Delta P_j}{\Delta t}
\]  

(3)

where:

- \( \Delta P_j \) - the value of the step change in reactor power.

In (3), the numerical solution is displayed in a spatial representation, which is written in the form of a Pade approximation. Accordingly, the theory of automated
control (3) can be interpreted as a reflection of the behavior of an object under step influence in the form of the second factor, then the expression in square brackets will be considered as a transfer function of the approximated object model.

At the 4th step, two-dimensional data are approximated (Fig. 1 and Fig. 2). The first argument is the time used to construct the graphs (Fig. 1 and Fig. 2) in the form (3). The second argument is the value of the least-squares step series (the value of the power conversion step series $\Delta P$) in the form (3) (essentially the 3rd stage).

The matrix equation used in our study is as follows:

\[
\begin{pmatrix}
\sum_{j=1}^{4}(\Delta P_j)^8 & \sum_{j=1}^{4}(\Delta P_j)^7 & \sum_{j=1}^{4}(\Delta P_j)^6 & \sum_{j=1}^{4}(\Delta P_j)^5 \\
\sum_{j=1}^{4}(\Delta P_j)^6 & \sum_{j=1}^{4}(\Delta P_j)^5 & \sum_{j=1}^{4}(\Delta P_j)^4 & \sum_{j=1}^{4}(\Delta P_j)^3 \\
\sum_{j=1}^{4}(\Delta P_j)^5 & \sum_{j=1}^{4}(\Delta P_j)^4 & \sum_{j=1}^{4}(\Delta P_j)^3 & \sum_{j=1}^{4}(\Delta P_j)^2 \\
\sum_{j=1}^{4}(\Delta P_j)^4 & \sum_{j=1}^{4}(\Delta P_j)^3 & \sum_{j=1}^{4}(\Delta P_j)^2 & \sum_{j=1}^{4}(\Delta P_j)^1
\end{pmatrix}
\begin{pmatrix}
a \\
b \\
c \\
d
\end{pmatrix} =
\begin{pmatrix}
f_1(t) \\
f_2(t) \\
f_3(t) \\
f_4(t)
\end{pmatrix}
\]

(4)

The solution to this matrix equation is as follows:

\[
\begin{pmatrix}
a \\
b \\
c \\
d
\end{pmatrix} = [K^{-1} \cdot M] \cdot F.
\]

(5)

where:

$f_i(t)$ - a function of the form (3), where each curve (Fig. 1 and Fig. 2) was approximated separately;

$a, b, c, d$ - the coefficients of the power series that describe the entire volume of the original data (Fig. 1 and Fig. 2).

The resulting expression (5) with $f_i(t)$ in the form of (3) can be considered an approximated model (control object approximation).

**Conclusions.** The proposed model of object approximation control makes it possible to use the transfer function of the process that takes place inside a nuclear reactor. The results obtained on the basis of the nonlinear physical and mathematical model "control object physical" are adequate for a certain time interval with the same initial data, which allows to create an automated control system that can compensate for the reactivity caused in a nuclear power plant due to internal and external disturbances. Unfortunately, the approximated model "control object approximation" cannot be used for the entire period of time, but the model can be used in a certain range of automated control system regulators. This makes it possible to calculate new parameters of the presented approximated model during this time interval in order to reconfigure the necessary regulators without changing the structure of the model itself.
References:


