Modelling of power distribution control processes in the cores of VVER-1000 reactors using ANC-H reactor core simulator program

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Background

- Due to the conversion of Ukrainian NPPs to Westinghouse fuel and the difficult situation in the Ukrainian power system characterized by periodic rocket attack of critical infrastructure by the russian federation, it became necessary to quickly unload NPPs during rocket attack and, accordingly, to issue a power unit unloading forecast to the control room operational personnel taking into account current restrictions on nuclear fuel operation.
- For these purposes, a graphical program was developed for computational modelling and forecasting of power management processes in VVER core using the ANC-H code - ARCS (ANC-H Reactor Core Simulator).
- The ARCS program is designed for computational modeling of power distributions processes in the cores of VVER-1000 reactors using the ANC-H code. The ARCS software tool is a graphical user interface that allows you to conveniently perform control actions (change power, position of the control bank, etc.) and perform a computational forecast of the core parameters using the ANC-H code and display information in text and graphical form. In terms of functionality, the ARCS program is similar to the IP program.

Brief information about the ARCS program (1)

Currently, two modes are available: “Dialog” and “Table”.

The main mode selection window is shown in Figure 1.

The general view for the “Dialog” mode is shown in Figure 2.

The “Dialog” mode allows the user to manually perform the necessary control actions (change of power, position of the control bank, criticality etc.) and immediately see the results.

Control actions are set using the “Control Panel” window Figure 3.

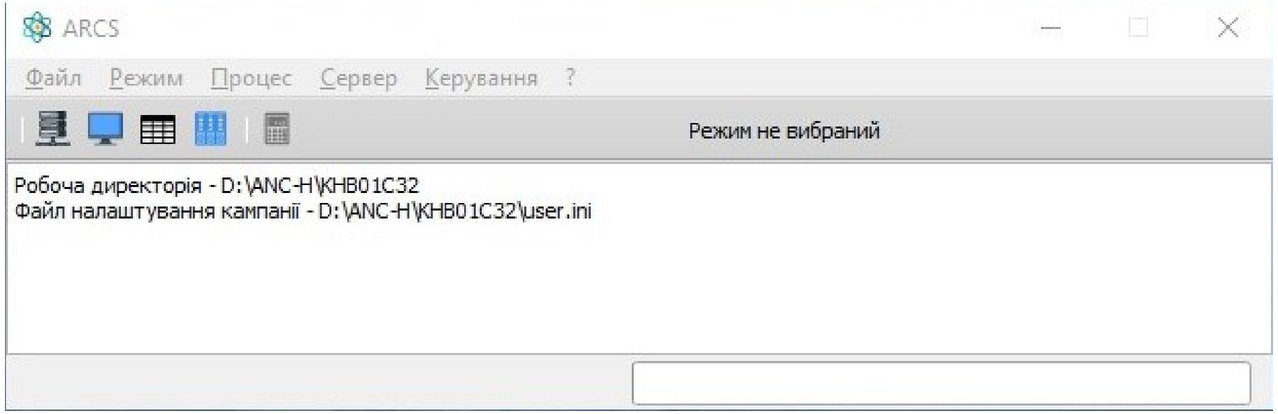

Figure 1 Main mode selection window

Brief information about the ARCS program (2)

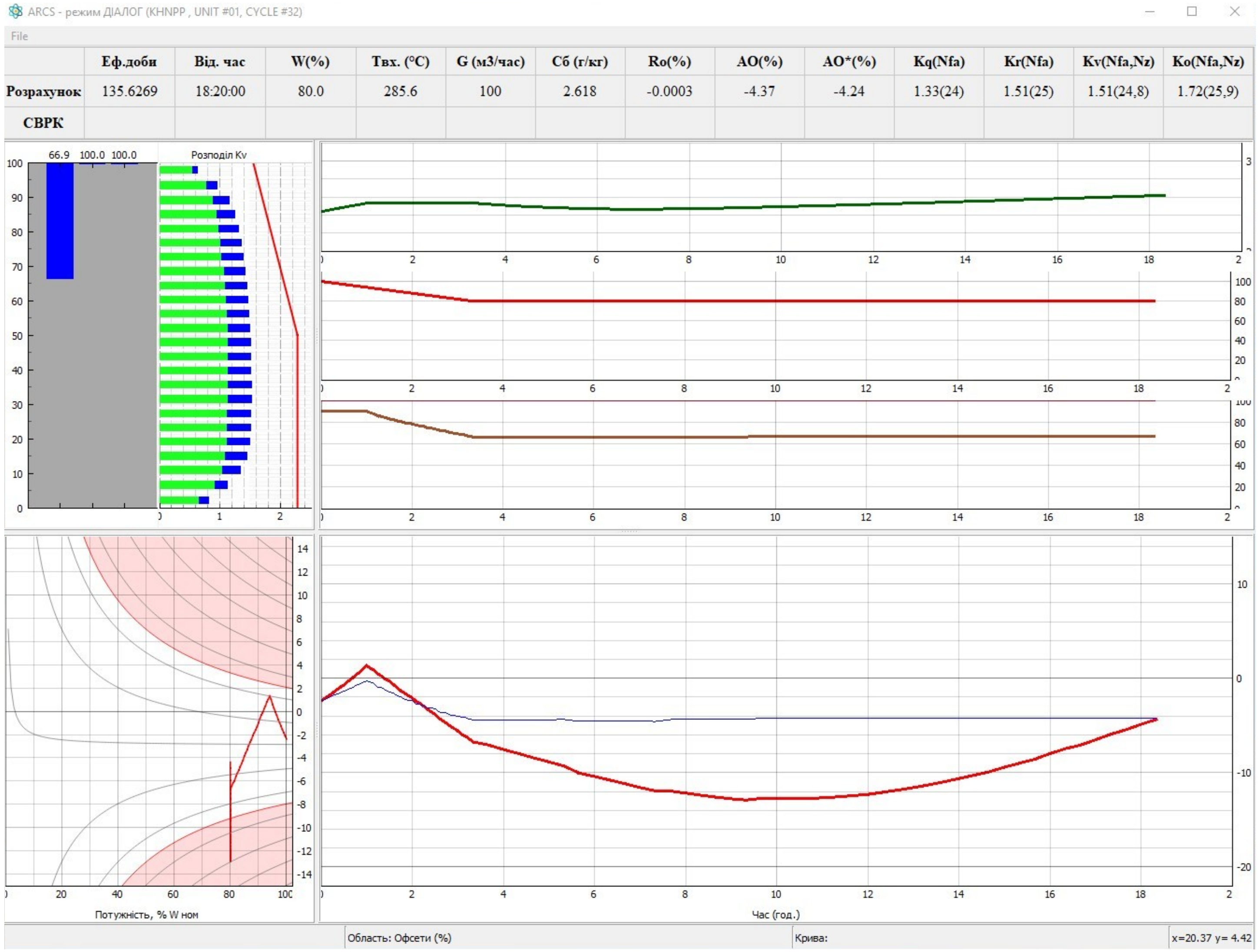

Figure 2 General view for the “Dialog” mode

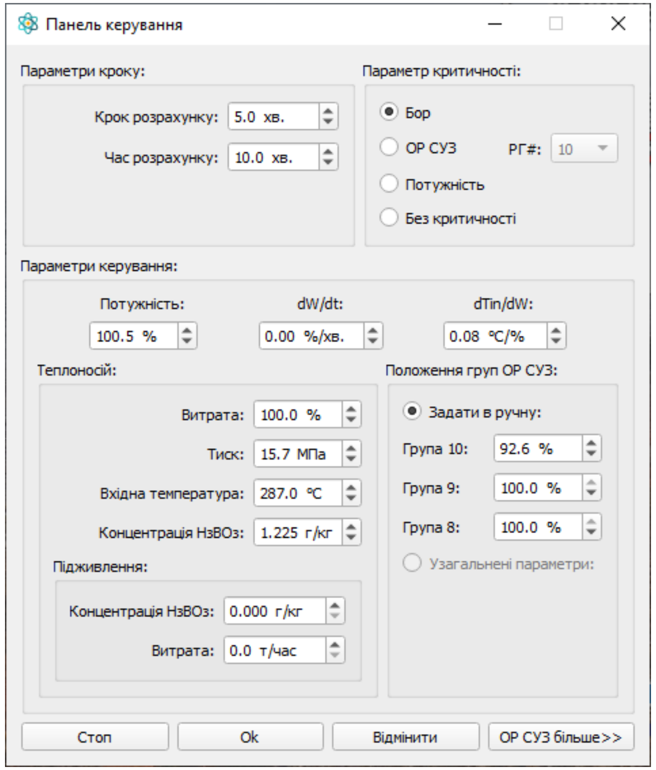

Figure 3 Control Panel window

Brief information about the ARCS program (3)

- The "Table" mode allows the user to enter all the necessary data for modeling the transition process in tabular form. This is convenient, for example, for comparison with actual operating data. Once the data in the table is complete, the program automatically switches to 'Dialog' mode.
- It should be noted that the ARCS program is not a calculation code, but only a graphical user interface for the ANC-H code. Accordingly, the ARCS program settings are similar to the settings for performing calculations for the ANC-H code.
- In general, to start modeling, you need to specify the path to the ANC-H databank and the state ID, which contains information about the initial state of the calculation (burnup, position of CR, Xe, Sm, etc).
- To confirm the ability of the ARCS software tool to adequately perform computational modeling and forecasting of power distribution management processes in the core of VVER-1000 reactors, validation was performed using real operational data on unloading/loading that occurred at the power units of the South Ukraine NPP, Rivne NPP and Khmelnytskyi NPP.
- All calculations for comparison were performed using the "Table" mode.

Brief information about the ARCS program (4)

Figure 4 General view for the “Dialog” mode

Unit #2 SUNPP

For unit #2 of the SUNPP modeling of the transition process was performed for the 34th fuel cycle, which took place on 184.28 effective power days.

A map of the 34th fuel cycle is provided at Figure 5. As can be seen from the map, the core consists entirely of Westinghouse fuel assemblies

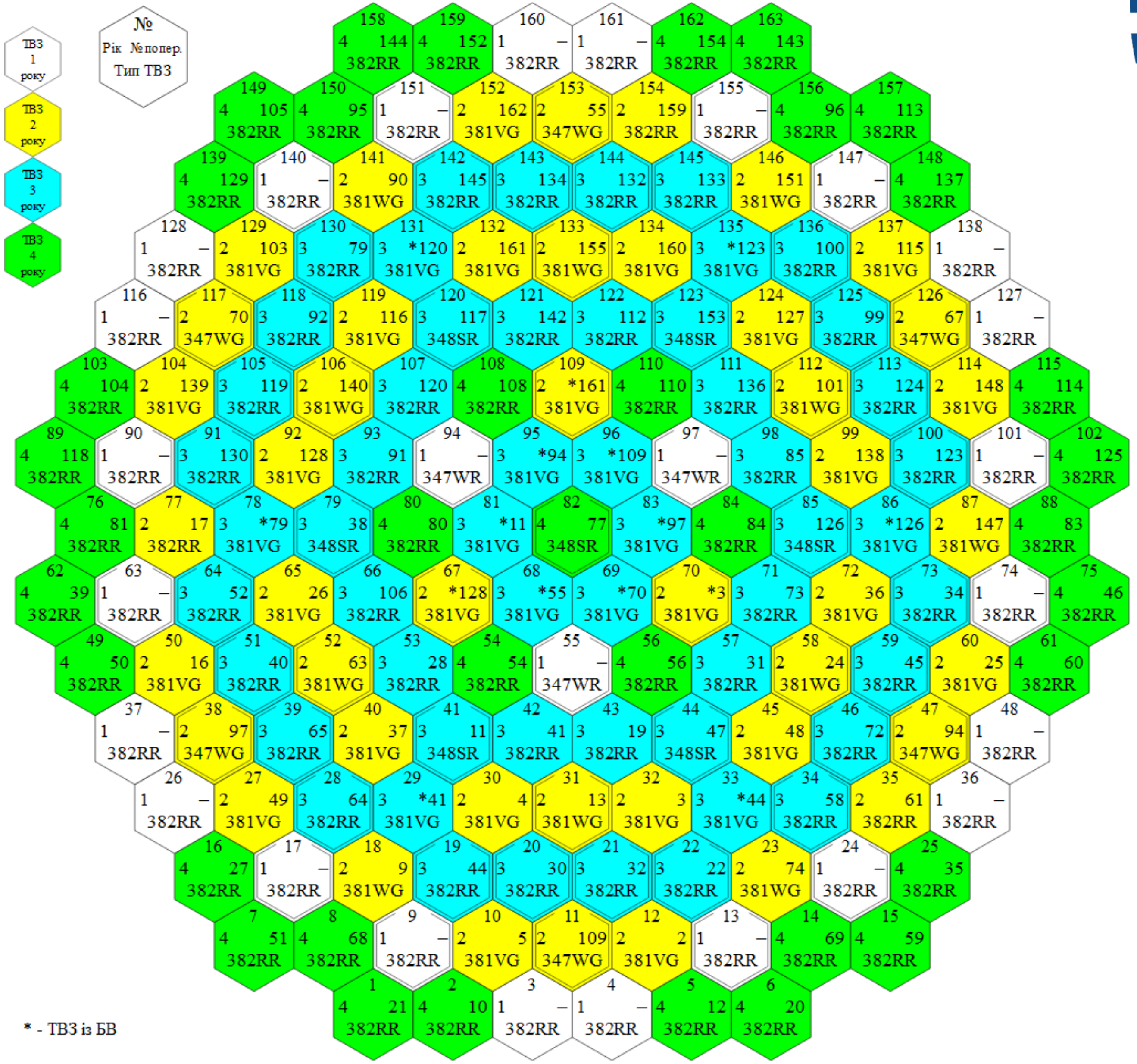

Figure 5 Map of the 34th fuel cycle of unit #2 of the SUNPP

Unit #2 SUNPP

As can be seen from the calculation results, the calculated AO closely matches the AO calculated by the SVRK (Kruise).

For this transition process, the RMS for axial offset is 0.7%, and the RMS for boric acid concentration is 0.1 g/kg

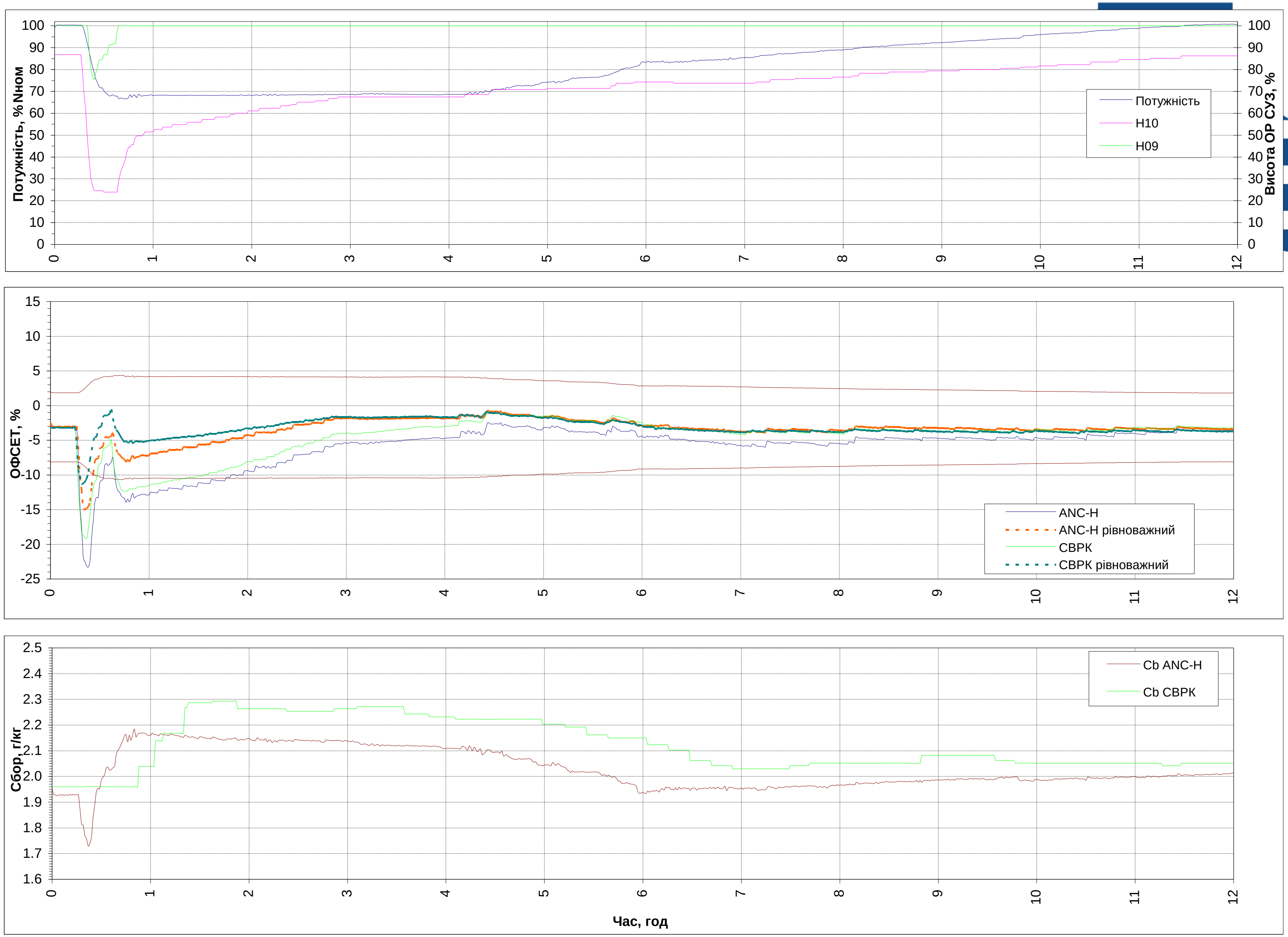

Figure 6 Results of calculating AO values based on actual changes in the parameters of unit #2 of SUNPP

Unit #3 SUNPP

For unit #3 of the SUNPP modeling of the transition process was performed for the 31st fuel cycle, which took place on 229.08 effective power days.

A map of the 31st fuel campaign is provided at Figure 7. As can be seen from the map, the core consists entirely of Westinghouse fuel assemblies.

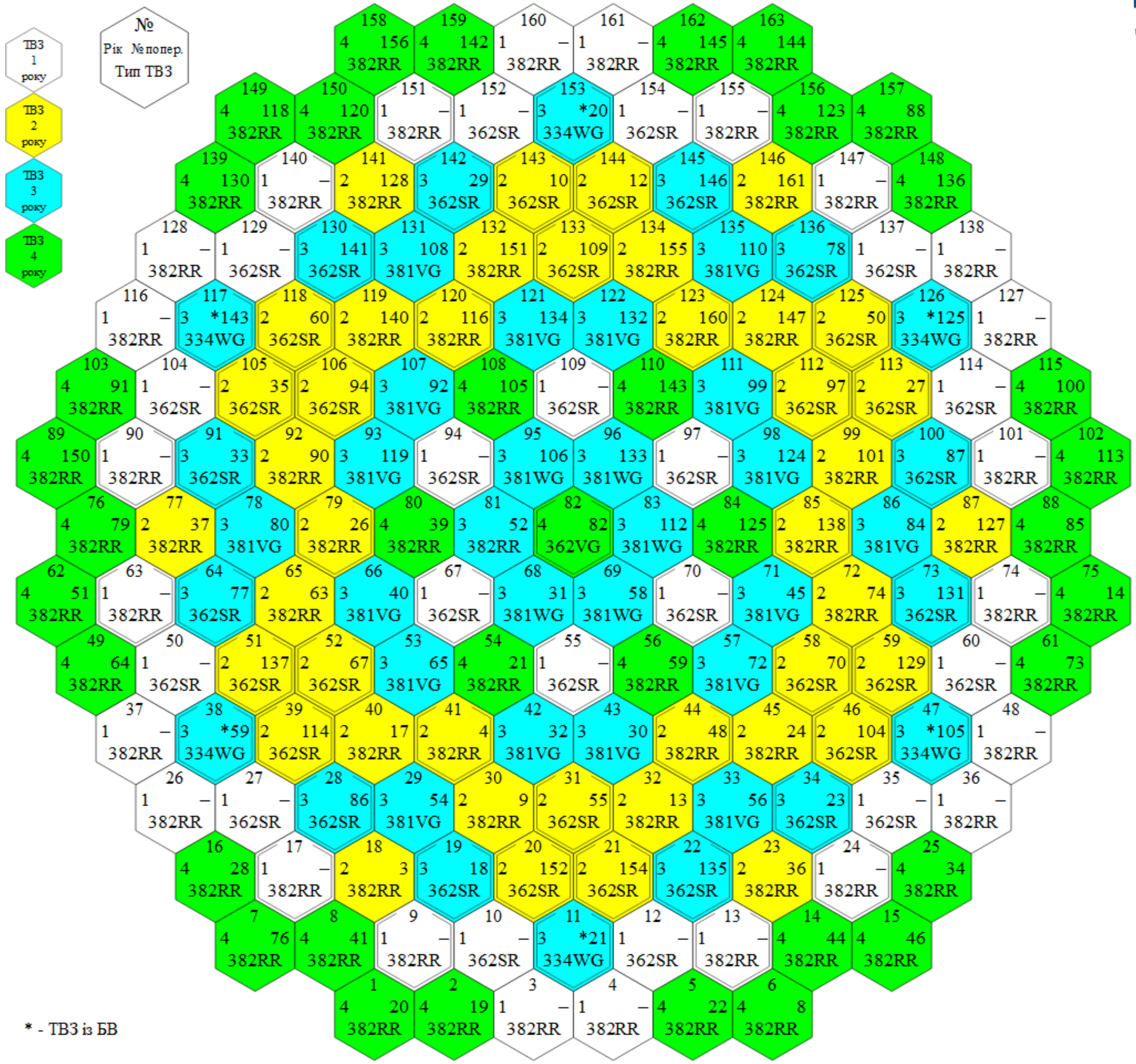

Figure 7 Map of the 31st fuel cycle of unit #3 of the SUNPP

Unit #3 SUNPP

As can be seen from the calculation results, the calculated AO closely matches the AO calculated by the CMS BEACON.

For this transition process, the RMS for axial offset is 1.1%, and the RMS for boric acid concentration is 0.1 g/kg

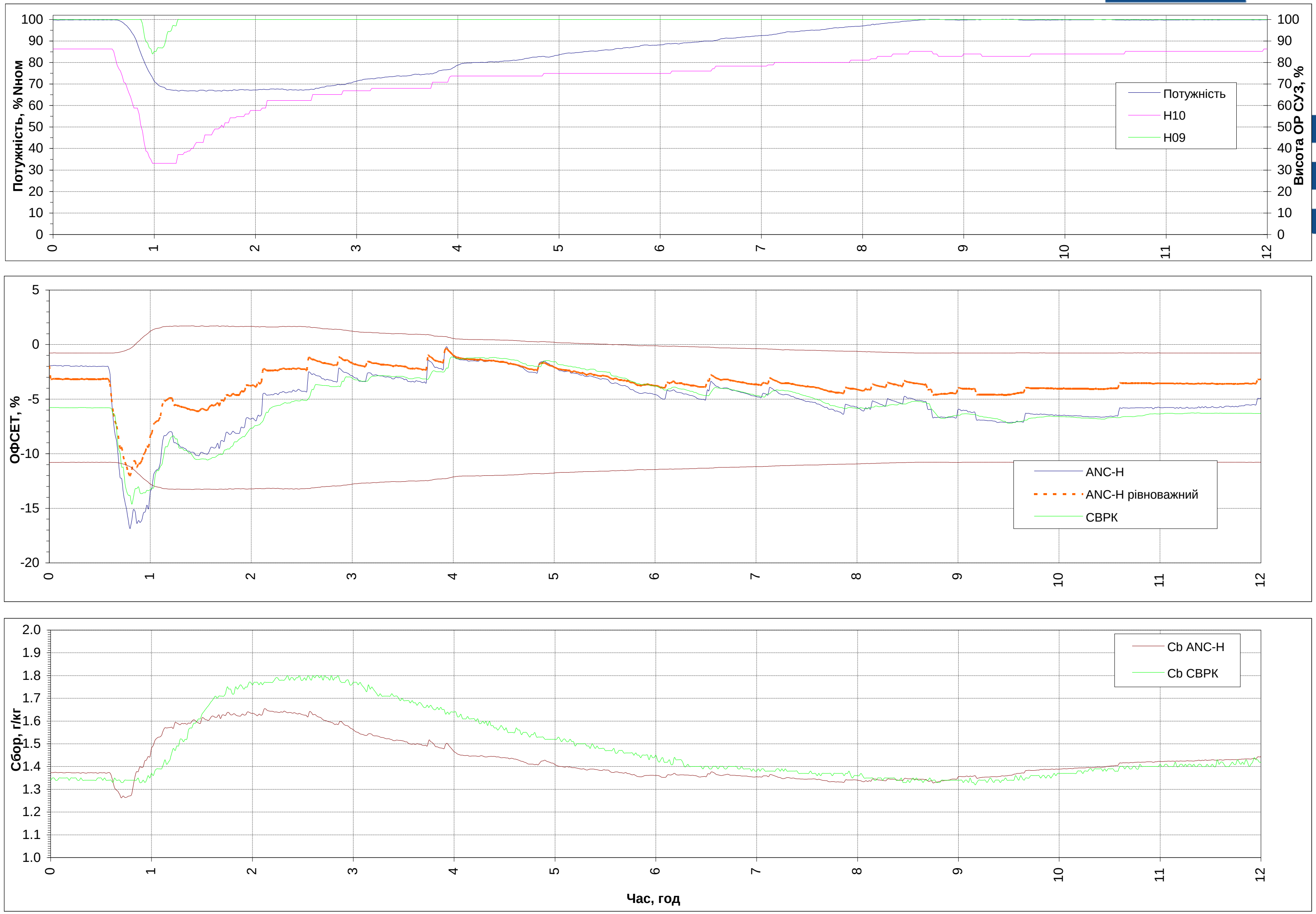

Figure 8 Results of calculating AO values based on actual changes in the parameters of unit #3 of SUNPP

Unit #3 RVNPP

For unit #3 of the RVNPP modeling of the transition process was performed for the 32nd fuel cycle, which took place on 126.26 effective power days.

A map of the 32nd fuel campaign is provided at Figure 9. As can be seen from the map, the core consists entirely of Westinghouse fuel assemblies.

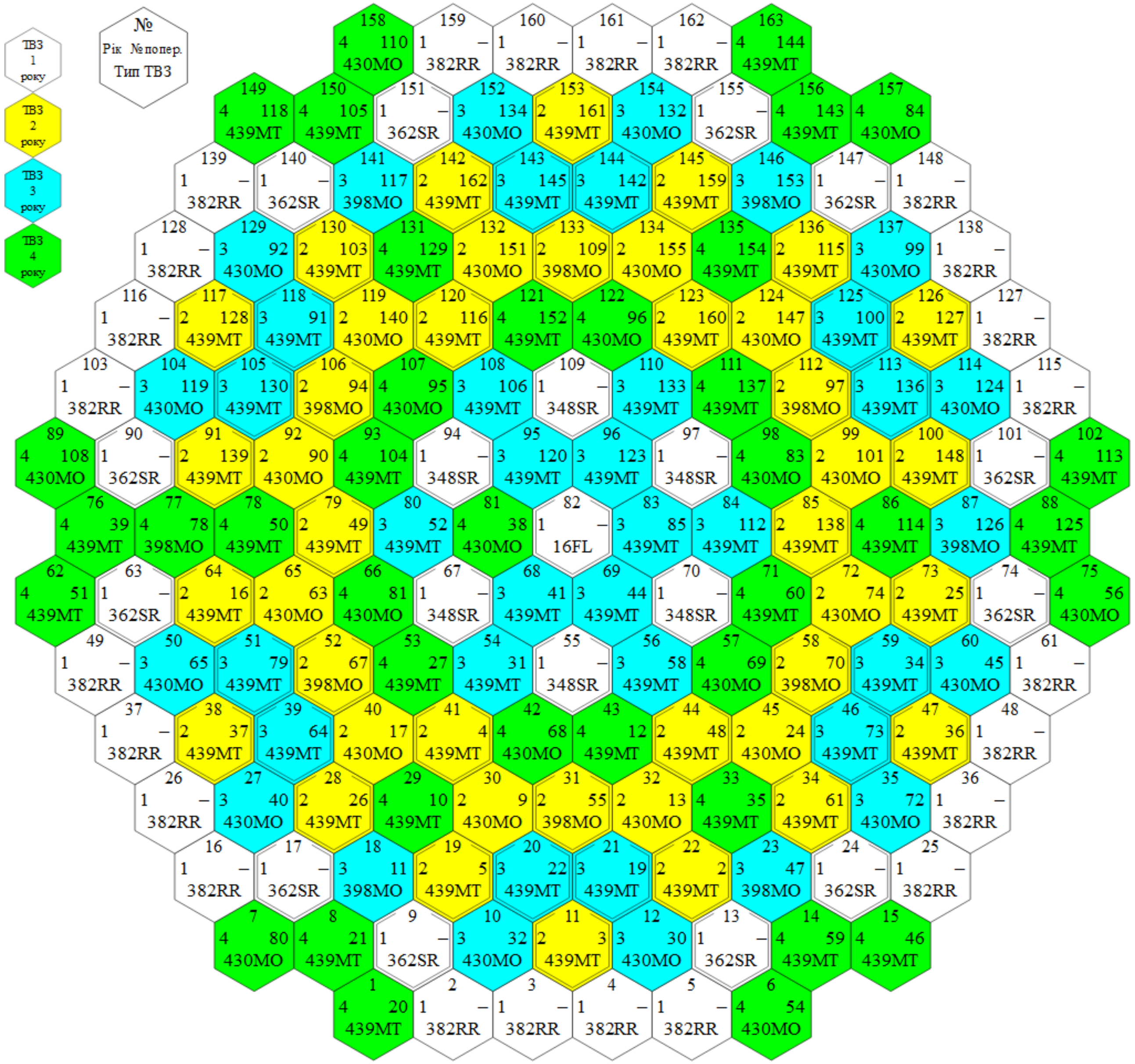

Figure 9 Map of the 32nd fuel cycle of unit #3 of the RVNPP

Unit #3 RVNPP

As can be seen from the calculation results, the calculated AO good matches the AO calculated by the CMS BEACON.

For this transition process, the RMS for axial offset is 1.8%, and the RMS for boric acid concentration is 0.1 g/kg

Figure 10 Results of calculating AO values based on actual changes in the parameters of unit #3 of RVNPP

Unit #1 KHNPP

For unit #1 of the KHNPP modeling of the transition process was performed for the 32nd fuel cycle, which took place on 146.41 effective power days.

A map of the 32nd fuel campaign is provided at Figure 11. As can be seen from the map, the core consists entirely of TVEL fuel assemblies.

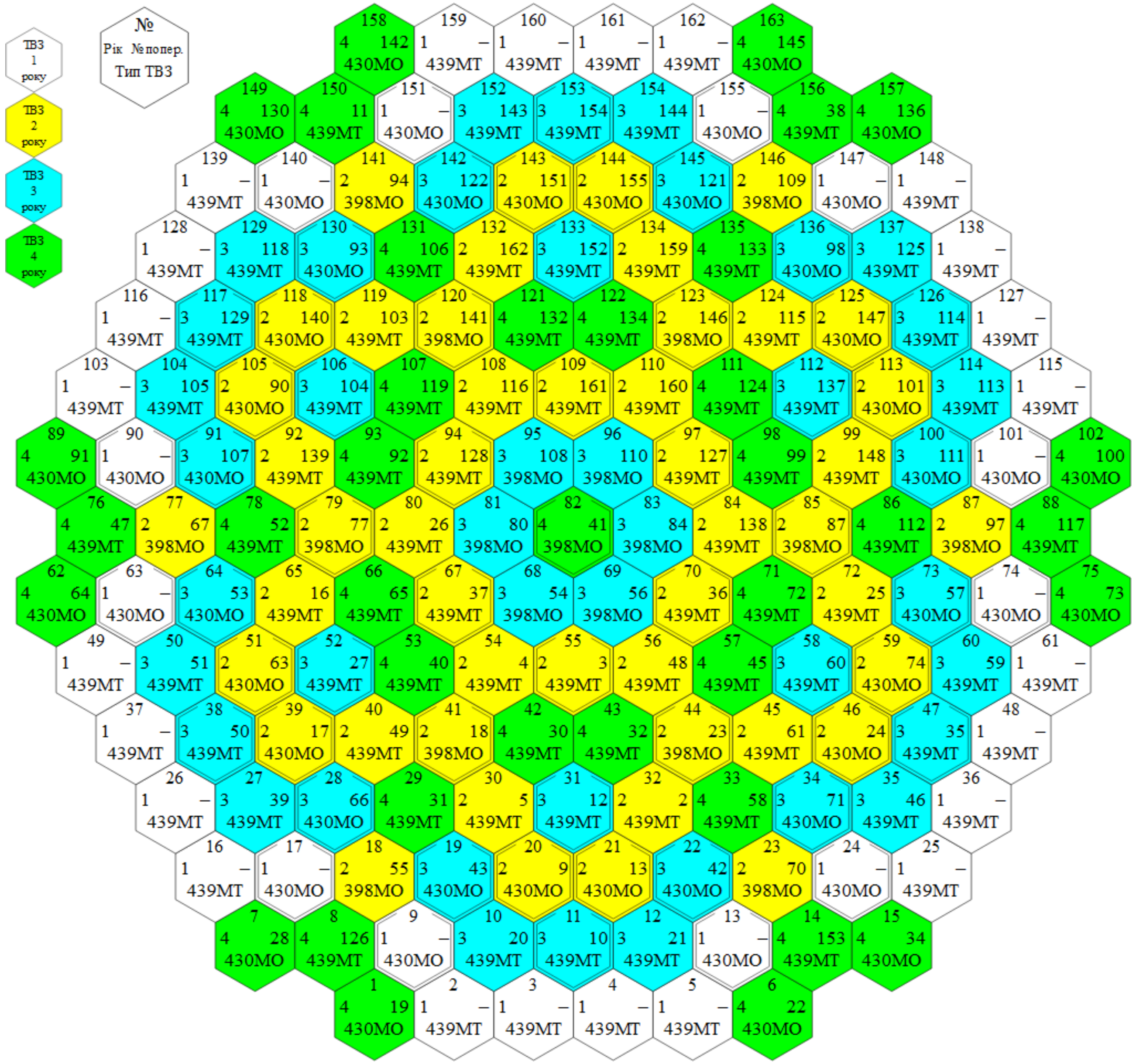

Figure 11 Map of the 32nd fuel cycle of unit #1 of the KHNPP

Unit #1 KHNPP

As can be seen from the calculation results, the calculated AO closely matches the AO calculated by the SVRK (Kruise).

For this transition process, the RMS for axial offset is 2.4%, and the RMS for boric acid concentration is 0.1 g/kg

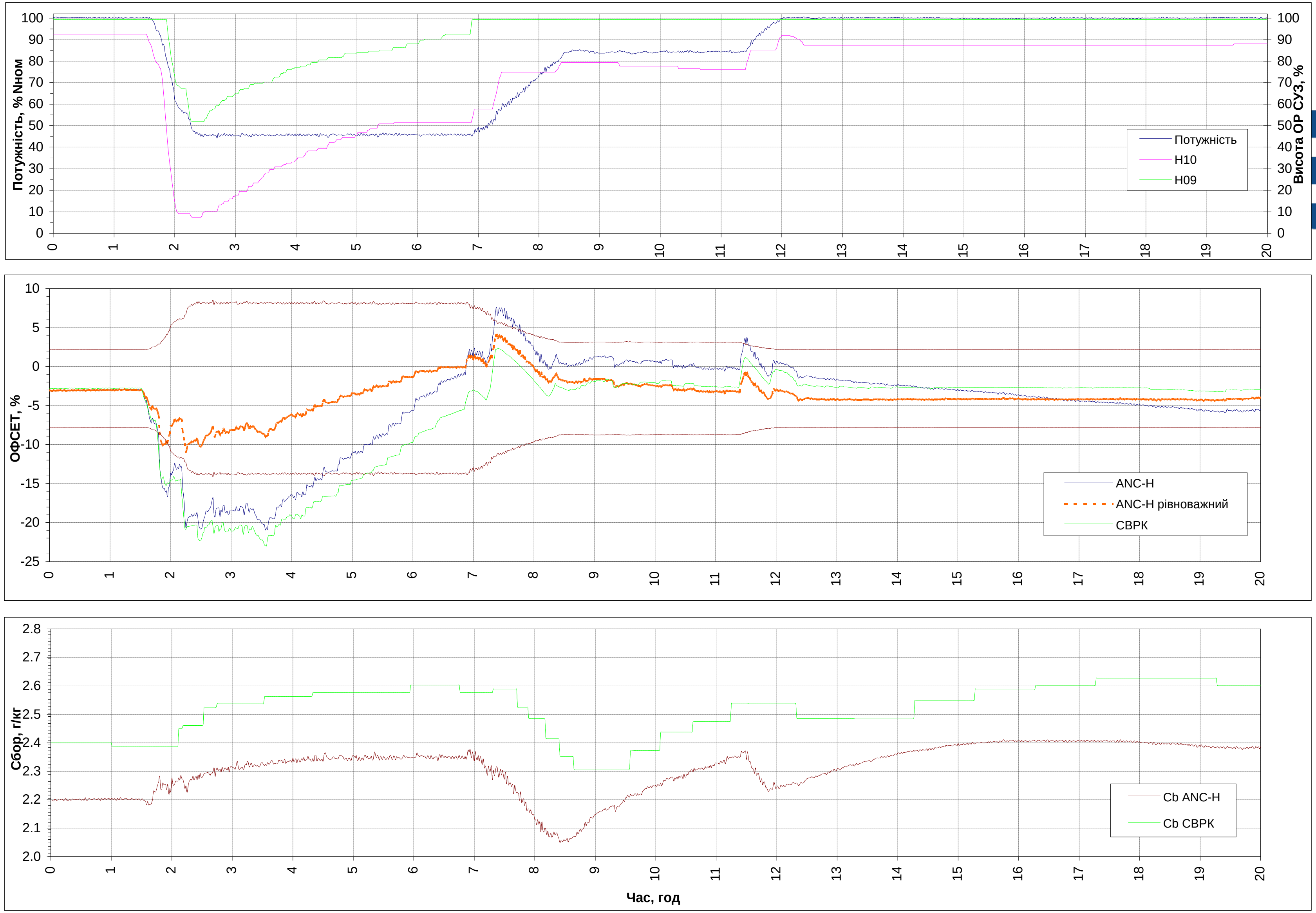

Figure 10 Results of calculating AO values based on actual changes in the parameters of unit #1 of KHNPP

Conclusions

- Validation calculations of transient processes for Ukrainian NPPs using the ARCS program showed that the maximum value of the RMS for axial offset is no more than 2.4%, and the maximum value of the RMS for boric acid concentration is no more than 0.2 g/kg, which is a good convergence of the calculated data with the experimental values and confirms the correctness of the selected approaches to modelling transient processes and the correctness of the input data formation and display of the calculation results.
- Thus, the ARCS program can be used to perform a computational forecast of the state of VVER-1000 cores both for fuel assemblies consisting of fuel assemblies from JSC TVEL, mixed fuel assemblies TVS-A and TVS-WR (transient fuel cycles) and for fuel assemblies consisting entirely of fuel assemblies from Westinghouse

Thank you for your attention!