AI-Based Autonomous Cell Control in RA-550 Cell Technology

Victor Mann[1], Yuriy Shtefanyuk[2], Vitaliy Pingin[3], Mikhail Grinishin[4] and Iliya Puzanov[5]

1. Technical Director
2. Director of the Moscow office of RUSAL IP.

RUSAL Management JSC, Moscow, Russian Federation

3. Director, R&D Aluminum
4. Director, Process Automation
5. Director, High-Amperage Cell Technologies

RUSAL Engineering and Technology Center, Krasnoyarsk, Russian Federation

Corresponding author: Iliya.Puzanov@rusal.com

Abstract

In view of the rapid growth of computing capacities and the continuing development of digital equipment, it becomes quite important to use new tools to timely control the aluminum smelting process, predict operational perturbations, and autonomously make process control decisions to achieve optimal cell performance.

To control the RA-550 cell technology, a number of artificial intelligence (AI) tools have been developed and deployed, such as smart sensors, Big Data analysis systems, digital twins, and neural networks for machine learning. New sensors, both physical and smart, replaced some direct physical (manual) measurements and enabled real-time predictions of those data that had been previously inaccessible for direct physical measurement due to the lack of appropriate tools.

The Big Data analysis systems help reveal unique hidden patterns, predict process scenarios, including process abnormalities, and ensure an early detection of sick pots. The digital twins allow one to timely control the process, simulate potential long-term cell behavior under various conditions and have a better understanding on how to reach target cell performance.

Machine learning enables to understand an individual response of a cell (or a group of cells) to input changes. In addition, the digital twin allows teaching personnel different techniques related to optimal process control and AI system servicing.

In this paper, we would like to elaborate on some individual, shelf solutions we have obtained as a result of developing an AI system to control the RA-550 cell technology.

Keywords: Cell technology, Detection of process disruptions, Predictive models, Digital twin, RA-550 cell technology.

1. Introduction

Aluminum production is a complex process. It requires considerable human resources to continuously monitor and manage the process in order to ensure optimum productivity and avoid any possible process deviations. In view of the rapid growth of digital resources and artificial intelligence (AI) instruments, it now becomes possible to delegate some tasks, such as process control and problem/disturbance identification, to artificial intelligence (AI). By doing so, human resources become free to be used for solving rather complicated problems, or untypical problems. The use of smart sensors allows reducing the number of physical measurements. Moreover, AI-

based process control allows establishing efficient process control algorithms and avoiding some deficient individual practices.

The most intensively developing RUSAL's cell technology, RA-550, incorporates AI tools providing for autonomous cell control. This paper describes some instruments and tools that are used by the RA-550 cell technology – such as virtual sensors, Big Data, digital twins and machine learning – for solving a number of particular tasks.

2. Main AI Tools Used by the RA-550 Cell Technology

2.1 Virtual Sensors

Virtual sensors are a tool capable to replace physical measurements. The sensors and data processing algorithms allow obtaining accurate and reliable values of various process parameters. They help optimize controls and reduce the human factor impact. In some cases, they help measure those parameters that are inaccessible for direct physical measurement and, thus, enhance management and control efficiency.

Software sensors supplement the capabilities of the virtual sensors and allow obtaining additional data and information regarding a system. The software sensors may be developed based on the algorithms and models that analyze input data and output particular data regarding processes and parameters. The virtual sensors are the key component of the RA-550 cell technology. Using AI, the sensors replace physical measurements and allow obtaining more accurate data regarding a large number of process parameters. As a result, it reduces both the need for direct operator interventions and the human factor impact, which helps increase productivity and decrease costs.

2.2 Big Data

The application of AI in the RA-550 cell technology allows analyzing more data. Quite a large amount of data obtained from all available sources is processed using AI algorithms that identify latent, or unobvious, relationships and correlations. AI interprets such data and generates a problem-solution map, which helps make more accurate and reasoned decisions.

2.3 Digital Twins

Digital twins are a virtual model of real systems and processes, which allows conducting a comprehensive analysis of how different external actions, or factors, may influence a process or affect a system. In the case of the RA-550 cell technology, the digital twin is used to predict parameters and their values. The digital twin allows simulating different multi-factor scenarios, conducting experiments without any risk for real, on-site processes and improving the efficiency and accuracy of process control.

An additional tool based on the digital twin is a training tool for personnel, for both novices and experienced persons. Simulation-based training is the most efficient way of staff training, which allows considerably improving the professional level of staff, so that they become enabled to solve more complicated process issues.

2.4 Machine Learning

The use of machine learning algorithms in the RA-550 cell technology allows conducting neural network analyses and identifying individual features of systems and processes, both in relation to one individual RA-550 cell and a group of RA-550 cells. The algorithms allow optimizing a

both the interface and the contents: new tests teaching to identify different situations, theoretical materials regarding more complex control algorithms, etc. Here, the most important thing is its application and testing on the personnel.

It is also important to continuously verify both real and virtual algorithms (to see if they match), to supplement magnetic field libraries, to enhance the communication between the virtual cell and the ELVIS software, etc., and such work is continuously done.

Also, software documentation (User guides for different software) has been developed. It will help in the operation of the software.

9. References

1. Tatyana Penkova et al., Application of Ensemble Algorithms to Detect Anode Effects in Aluminum Production, *Proceedings of SibDATA 2021 – The 2nd Siberian Scientific Workshop On Data Analysis Technologies*, June 25, 2021, Krasnoyarsk, Russia, 79-85.
2. Tatyana Penkova et al., Application of Association Rule Mining to Detect "Anode Spike" Disruptions in Aluminum Production*, Proceedings of SibDATA 2021 – The 2nd Siberian Scientific Workshop On Data Analysis Technologies*, June 25, 2021, Krasnoyarsk, Russia, 10-16.
3. Andrey Zavadyak et al., Transfer processes in the bath of high amperage aluminium reduction cell*, Proceedings of TMS 2019 Annual Meeting & Exhibition*, San Antonio, March 10-14, 2019, *Light Metals 2019*, 773-777.
4. Viktor Mann et al., RA-550 cell technology: UC RUSAL's new stage of technology development, *Proceedings of TMS 2018 Annual Meeting & Exhibition*, Phoenix, March 11-15, 2018, *Light Metals 2018*, 715-719.
5. Viktor Mann et al., RA-550: The new generation of cell technology at UC Rusal, *Light Metal Age,* 2017, Vol. 75, No. 1, 22-25.
6. Viktor Mann et al., Increase of amperage at Sayanogorsk aluminum smelter, *Proceedings of TMS 2008 Annual Meeting & Exhibition*, New Orleans, March 9-13, 2008, *Light Metals 2008*, 281-285.
7. Iliya Puzanov et al., Mathematical Modeling of "Spikes" and their Influence on Current Distribution in a High-Amperage Cell*, Journal of Siberian Federal University. Processes and Technology*, No. 7, 2017, 862-873.
8. Iliya Puzanov et al., Mathematical Modeling of "Spikes" and their Influence on Current Distribution in a High-Amperage Cell, *Book of Abstracts of the 8th Non-Ferrous Metals and Minerals International Congress*, 12-15 September 2016, Krasnoyarsk, Russia, 68-69.
9. Iliya Puzanov et al., Improvement of the Prediction of Process Disturbances by means of the Continuous Monitoring of Anodic Current Distribution Data, *Journal of Siberian Federal University. Processes and Technology*, No. 6, 2016, 788-801.
10. Iliya Puzanov et al. Method of automatic control of disturbances in an aluminium cell, *Patent RU 2631077 C1*, filed Aug. 4, 2016, granted Sept. 18, 2017.
11. Iliya Puzanov et al., Method of automatic control of disturbances in an alumina feed system of an aluminium cell, *Patent RU 2631072 C1*, filed June 8, 2016, granted Sept. 18, 2017.
12. Iliya Puzanov et al., Method of automatic control of the bath ratio, *Patent RU 2540248 C2*, filed June 18, 2013, granted Feb. 10, 2015.
13. Andrey Zavadyak et al., Tools of intelligent assistance in the control over the process of identifying process disturbances and evaluating the state of an aluminum production facility, *Computer program registration certificate No. 2021662399*, granted July 27, 2021.
14. Tatiana Piskazhova et al., Virtual Cell, ver. 2.0, a counseling/training program, *Computer program registration certificate No. 2017612828,* granted March 3, 2017.