A Machine Learning Approach to Early Detection of Incorrect Anode Positioning in an Aluminum Electrolysis Cell

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Abstract

The Hall-Héroult process involves positioning very large anodes, weighing several tonnes, within a few millimeters of a given reference. Despite the continuous improvement of anode setting technologies and practices, there are still several cases where incorrect anode positioning impedes good cell performance. There is currently no reliable way to detect these abnormal situations before they become a problem.

The presented approach uses new sensors developed by Rio Tinto to continuously monitor current in individual anodes. Data from these sensors, together with machine learning techniques, have been used to elaborate an algorithm that predicts the anode current pickup which, in turn, is used to evaluate anode positioning. These sensors and model are currently being deployed on industrial cells and have been shown to greatly improve operators' decision making.

Keywords: Aluminum electrolysis cells, anode setting, anode positioning, continuous anode current monitoring, machine learning.

1. Introduction

Operating a Hall-Héroult cell typically involves replacing one or two anode assemblies every 24 – 36 hours. This operation is critical because it has the potential to significantly affect short-term cell performance, namely current efficiency (CE) and specific energy consumption. In fact, one of the most important challenges of any aluminum smelter is to keep the disturbance from the anode change to a minimum; thermal balance, alumina dispersion and current distribution are all directly affected by anode change to some extent. When it comes to changing an anode, there are several critical tasks, a crucial one being the positioning of the anode at the appropriate height where a precision of less than 5 mm is often expected.

Even with the latest technology, positioning large carbon blocks weighing several tons within a few mm of a reference is a difficult mission. Most smelters use the old anode as a reference; the goal is to set the bottom of the new anode at the same altitude as the bottom of the old one (plus a certain amount to account for the behavior of the new anode). This process, called gauging, relies on a number of references where many errors can add up: it is possible for the anode-cathode-distance (ACD) of the old anode to be incorrect in the first place, the stem of the new anode might be slightly angled resulting in a wrong measurement, the measurement equipment could be de-calibrated or include mechanical looseness leading to less-than-perfect results. Even with excellent operational practices, there are cases where anodes end up at an incorrect ACD after setting (5 – 10 % is typical).

It has been shown by many studies [1 – 4] that CE is related to the average ACD of a cell (Figure 1).

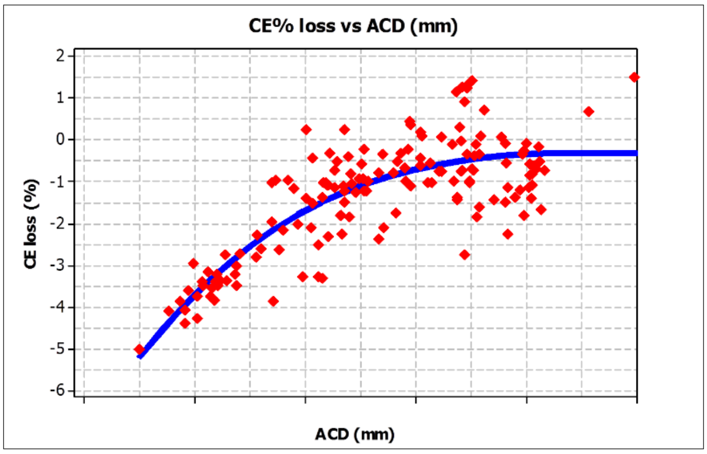

Figure 1. CE loss (%) as a function of ACD (mm) [4].

It is also believed, as studied by Tarcy [5] (Figure 2) that CE is strongly penalized by the anode drawing the most current – often the lowest one. As shown in Figure 3, this is coherent with calculations done with our own model. In addition, as stated by Segatz [6] *"the MHD stability strongly depends on the distribution of the ACD"*, which in turn also affects overall cell performance through other mechanisms [7].

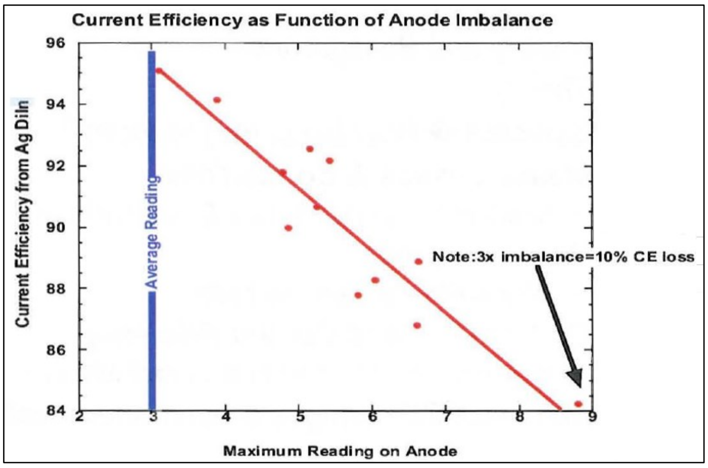

Figure 2. CE as a function of maximum anode current draw in a cell [5].

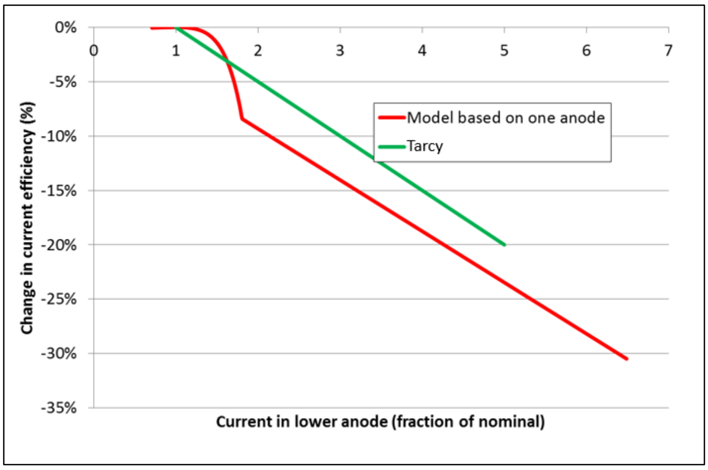

Figure 3. Superimposition of Rio Tinto model results and experimental curve (Figure 2).

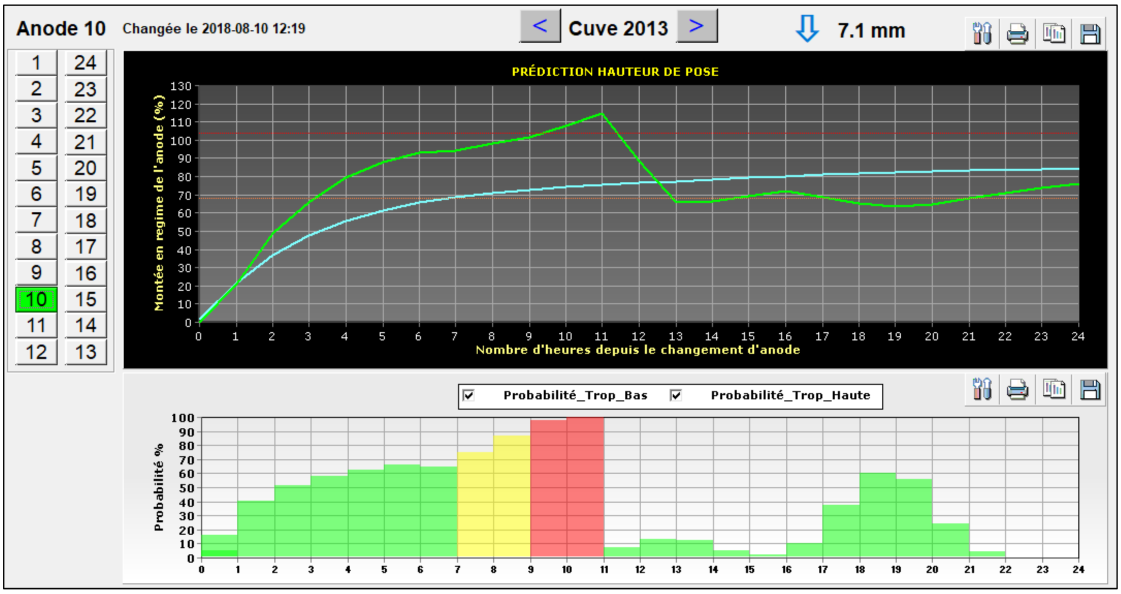

Figure 14. Example of a detection and correction after 9 – 10 h.

5. Conclusions

A model that detects incorrect anode positioning was presented. It uses the current pick-up after the anode change as an indicator of anode position and predicts the 24-hour old anode current, which is then compared to a target. The model was built using data from individual anode current sensors currently installed on industrial cells. These sensors are much more accurate in this context then the former approach using manual voltage drop measurements. These continuous measurements were a prerequisite to this work and could also be used in many other ways to tackle heterogeneity problems.

Machine learning was used to develop our model. Many approaches were tested and a final model was chosen based on its performance and maintainability. The chosen model, a normalized Radial Basis Function (RBF) network, automatically updates its references with recent information in order to adapt to changes. The maintainability of ML models is a potential pitfall of most machine learning algorithms.

The results are impressive; it is now possible to prevent a large proportion of incorrect positioning before it even affects the cell. A user interface was built to visualize the prediction in real-time and is currently used by cell operators where data from anodic current sensor are available.

6. References

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