AL02 - Rio Tinto Smelter 4.0: From Vision to Delivery

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Abstract

Significant progress has been made since Rio Tinto presented its Smelter 4.0 vision in 2017. In the field of automation, the first autonomous anode transport vehicle is currently being tested in the Alvance Aluminium Dunkerque smelter. Regarding remote activities, the Aluminium Operation Centre is delivering support to all Rio Tinto Atlantic Operation smelters, adding significantly to their value creation. The Technical Assistance 4.0 team does the same for Rio Tinto Aluminium Pechiney licensees. Virtual reality is now embedded into training modules. Mobile applications like Mobile KPI, SmartPot and APM4.0 are used to support operation and process. Closer to the pot, new sensors deliver information unavailable hitherto, which is stored in data lakes. New algorithms based on Artificial Intelligence drive the cell to its optimal performance. This article presents some of these concrete achievements of the Smart Cell, focusing on operator training, sensors, algorithms and cell performance.

Keywords: Smelter 4.0, smart cell, sensors, artificial intelligence, cell performance.

1. Introduction

Industry 4.0, the fourth industrial revolution, represents a new stage in the organization and control of the industrial value chain. In 2017 Rio Tinto delivered its Smelter 4.0 vision [1] with ambitious developments in automation, remote support, mobility and advanced control systems. The autonomous anode transport vehicle MAX (patented technology) is a good illustration of what we achieved in terms of automation (see Figure 1).

The first MAX series vehicle started its commissioning at the Alvance Aluminium Dunkirk plant at the end of 2019 and is currently being validated. MAX is a safe and environment-friendly anode transport solution, aiming at optimizing aluminium production operations. The vehicle is connected to an intelligent Fleet Management system, and can continuously and autonomously circulate within the plant, whether indoor or outdoor, safely operating and transporting loads up to twelve tonnes. Thanks to its guidance technology, MAX can be integrated into existing operations without any additional equipment.

Figure 1. Anode transport vehicle (MAX) with full load of anodes.

Regarding remote activities, our Aluminium Operation Centre based in Canada continues to deliver strong support to our Atlantic smelters. So does our AT4.0 team based in France for our external clients, using dedicated methodology and tools such as Radar™ [2]. These remote support centres have been and still are essential in the Covid-19 crisis we all face.

As technology evolves, it is also vital to continually improve the skills of our people to make sure that they will take appropriate decisions. Industry 4.0 technologies have been embedded into our training tools. Significant progress has also been made in enabling people to get real time information using a standard smartphone or a tablet. Cells have been equipped with new sensors providing data that are analysed with the latest data analysis techniques to develop new algorithms, which increase cell robustness and performance. These developments will be presented in the following section 2.

2. Improving and Maintaining the Skills of Operators and Technicians

2.1. What We Have Done Since 2010

We established a training system based on the BLOOM taxonomy [3]. People's knowledge is tested every two years, and methods of training include traditional face-to-face training, eLearning, remote training, on-the-job training, blended learning, and webinars. We have recently tested Virtual Reality (VR) training (Figure 2), which consisted of making live 3D videos of potline activities and embedding exercises to help students recognize electrical risks and to anticipate events in the potline. It has been designed to train everyone working in or passing through a potline about electrical hazards. Feedback from students encourages us to continue with this approach because it is flexible, affordable and feels real.

Figure 2. VR training session.

2.2. Our Current Developments

We are building a digital platform to provide access to all our learning content, based on students' needs. It aims at assessing students' skills and measuring gaps between their current skill level and the target. This covers not only general understanding but also specific tasks such as using the pot control system. The platform contains a Search Engine for students to find what they need, using traditional keyword search.

2.3. Our Future Development Path

Our purpose is to provide students with basic knowledge of our core business, in-depth knowledge of operating principles and mastery of specific situations. We aim to:

- Use VR for training novices, to learn new skills on a future technology or equipment, best practices, to identify risks, etc.
- Explore the Augmented Reality (AR) technology to enhance learning information in real-life situations
- Use a super-efficient network to exchange live 3D videos, with send-and-receive communication between 3-D camera and VR/AR helmet or glasses.

In addition, our vision of the taxonomy-based training system is to provide students with accurate learning content, in the most appropriate format, when and where it is needed. To implement this vision, we are looking into using artificial intelligence and a semantic approach [4] to index efficiently all our learning content, for accurate interpretation of and response to students' needs.

3. Mobile Applications

3.1. MESAL™

The MESAL Mobile KPI (Key Performance Indicator) application allows access to the Manufacturing Execution System database and also to external systems such as the ALPSYS pot controller and other applications. This application offers a single point of access to a plant KPI data lake to provide the plant management team with a global view of production and operations. It is available for IOS and Android devices (smartphone and tablet) either through a local Wi-Fi network or via 3G/4G access. Figures 3 and 4 show typical data displays from the MESAL system.

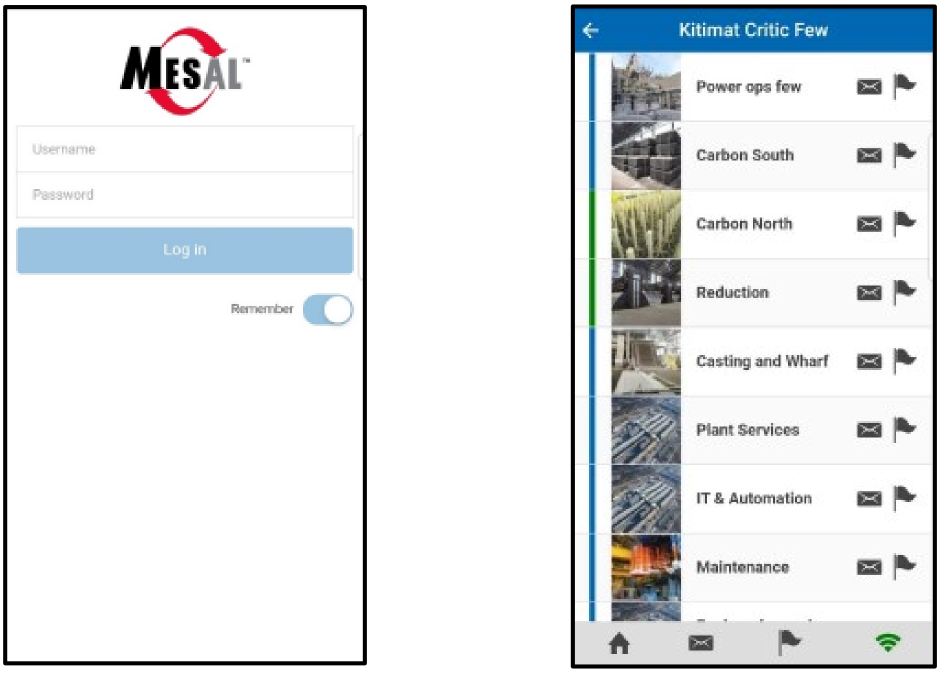

Figure 3. MESAL. Left: sign-in screen, Right: critical areas.

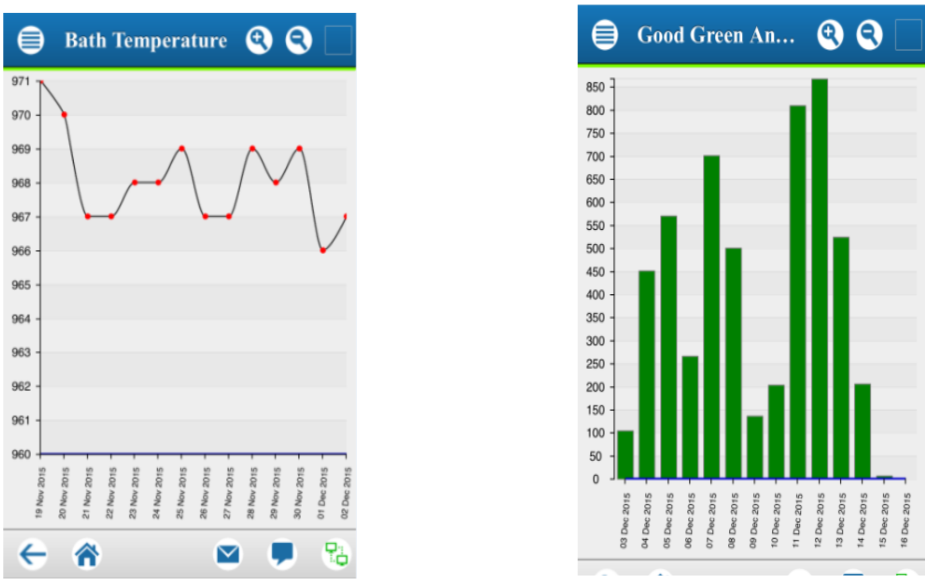

Figure 4. MESAL data display. Left: bath temperature, Right: good green anodes.

3.2. ALPSYS™

The ALPSYS pot controller modernization is continuing at a fast pace with several projects focusing on mobility.

An application is under development to give access to Level 2 screens from a smartphone or tablet. The next generation of the SmartPot system for hand-held devices will include wireless measurement capabilities to assist the operator during the measurement and immediately transfer measurements to the pot controller user interface (the Potmicro). There it will be possible to evaluate and possibly correct measurements, depending on the pot status at the time of the measurement (see Figure 5, Left).

The next generation of potmicro under industrial validation, the APM4.0, is also designed from the start for mobility. Its large graphic screens are designed so that they can be used from a remote personal computer (PC) or tablet (see Figure 5, Right). Moreover, the APM4.0 is equipped with an additional optical fibre connection to pot equipment, opening the way for IoT (Internet of Things) sensors or actuators.

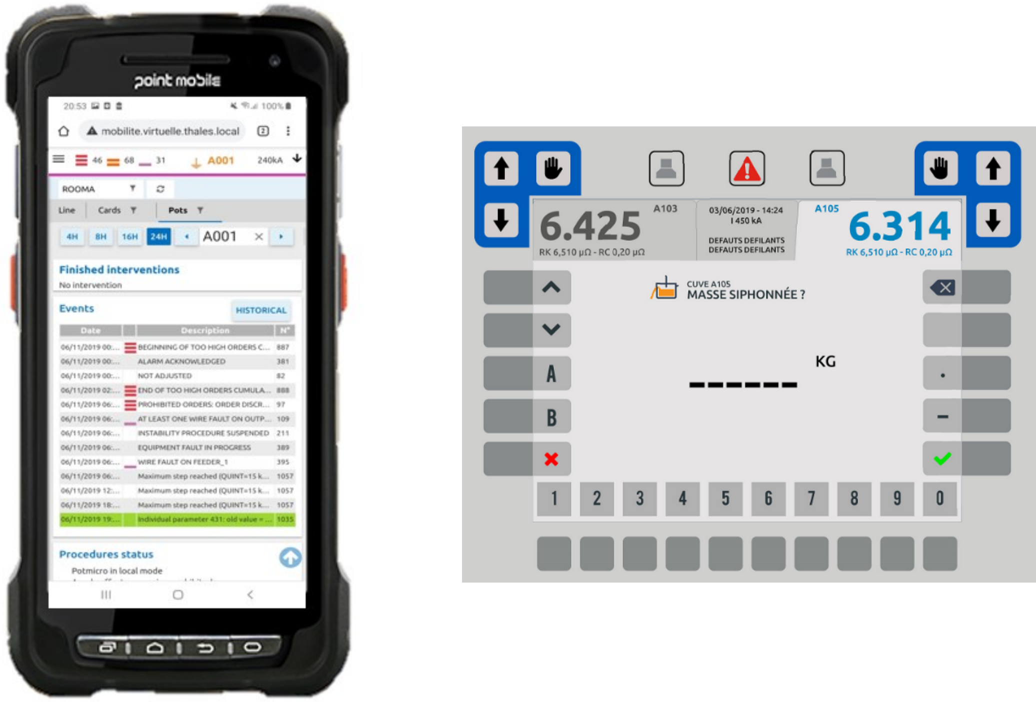

Figure 5. SmartPot system. Left: hand-held display of pot operating data, Right: typical APM4.0 graphic screen.

3.3. #hashTag: A New ALPSYS Module

Production is facing changes and process engineers need to test new approaches quickly. A new ALPSYS function known as #hashTag is about to be deployed, which allows them to create their own indicators on the fly. It enables the user to create new data (the “Tags”) based on existing ALPSYS data and on other Tags. Such Tags will then complement the existing ALPSYS database.

This brand-new module has three objectives:

1. To have an intuitive language and ergonomic interface
2. To include new indicators available immediately for present and past values
3. To be available everywhere where relevant in the ALPSYS & Radar suites.

4. Sensors

Our AP6X and APXe development cells are equipped with up-to-date measurement devices. These produce data that help us understand what is going on in the cell and then to develop algorithms accordingly. Figure 6 illustrates the scope and variety of the new sensors.

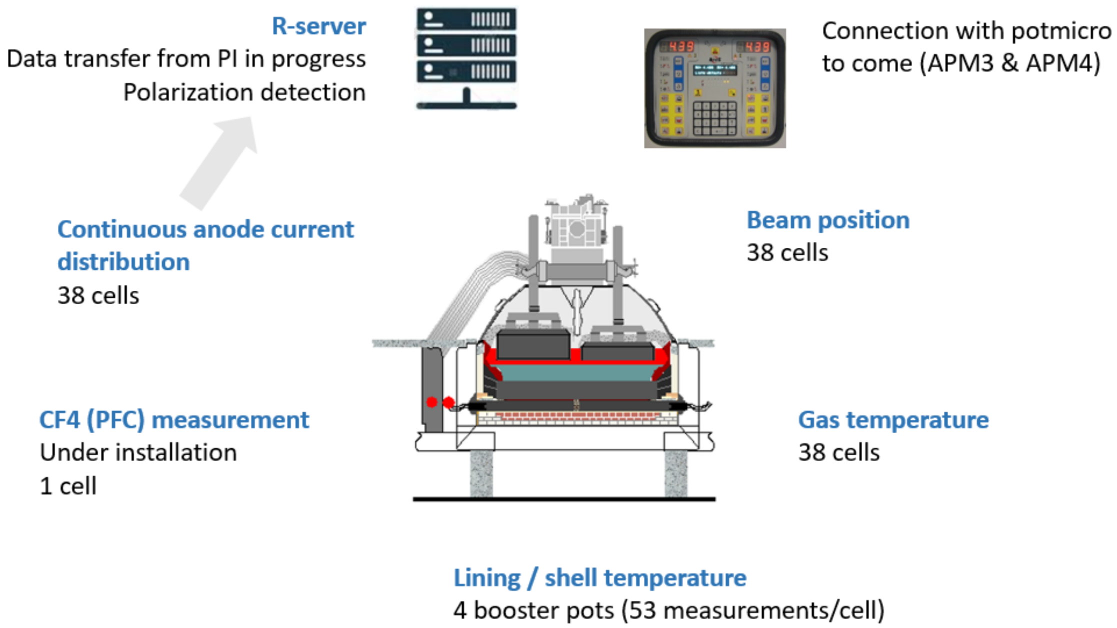

Figure 6. Data retrieved by the new sensors.

4.1. Temperature Monitoring in the Lining

For many years now, thermocouples have been installed on the external surface of the shell and in the lining of prototype cells in order the confirm model predictions.

Optical fibres have been installed in a prototype APXe cell at St-Jean de Maurienne, as seen in Figure 7 (Left). These enable real-time measurement of the temperature distribution on the pot bottom, using DTS Raman spectroscopy with ± 0.1 °C accuracy, measurements being made every 20 cm and every minute (Figure 7, Right).

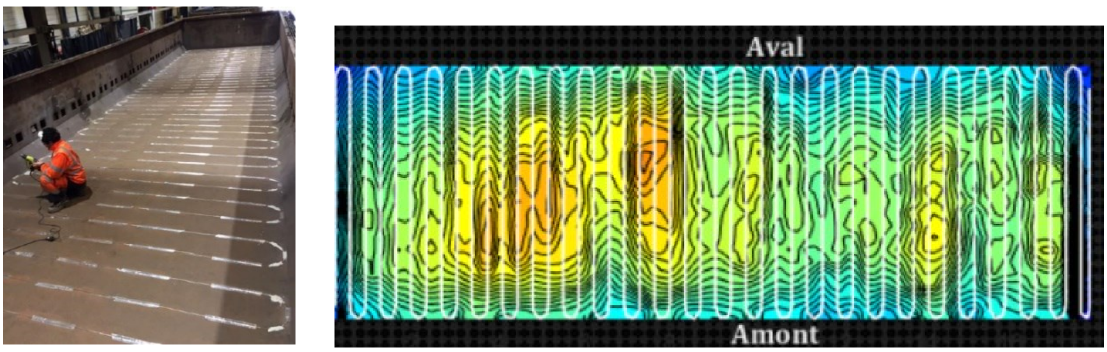

Figure 7. Instrumented APXe cell. Left: installing the optical fibre, Right: pot bottom temperature display, ranging from blue (cold) to red (hot).

4.2. Perfluorocarbon (PFC) Emissions

Online monitoring of PFC emissions is available on a prototype AP60 cell, using a Fourier Transform Infra-Red GASMET DX4000 spectrometer, as illustrated in Figure 8.

Figure 8. Online monitoring of PFC emissions. Left: electronics cabinet, Right: spectrometer.

PFC emissions are investigated, specifically those relating to low voltage conditions (see Figure 9). In some pot designs these cover up to 50 % of total PFC emissions.

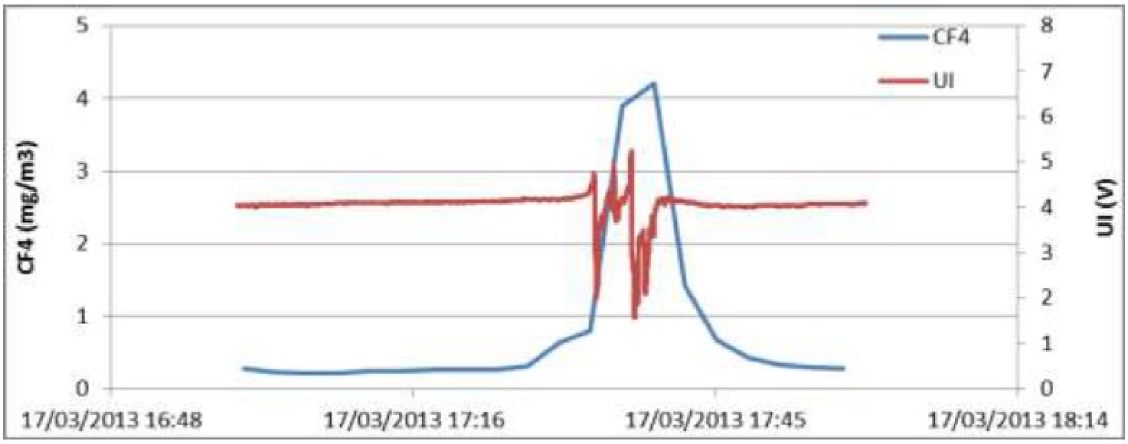

Figure 9. Display of CF_4 emissions and pot voltage (UI).

4.3. Pot Gas Temperature

Since the AP60 plant is located in the centre of the city of Saguenay in Québec, Canada, its HF emissions must be as low as possible. In order to detect open hoods or doors, thermocouples have been installed on all pots. Figure 10 shows the typical variation of exhaust gas temperature in a pot together with the reasons for the various sudden dips.

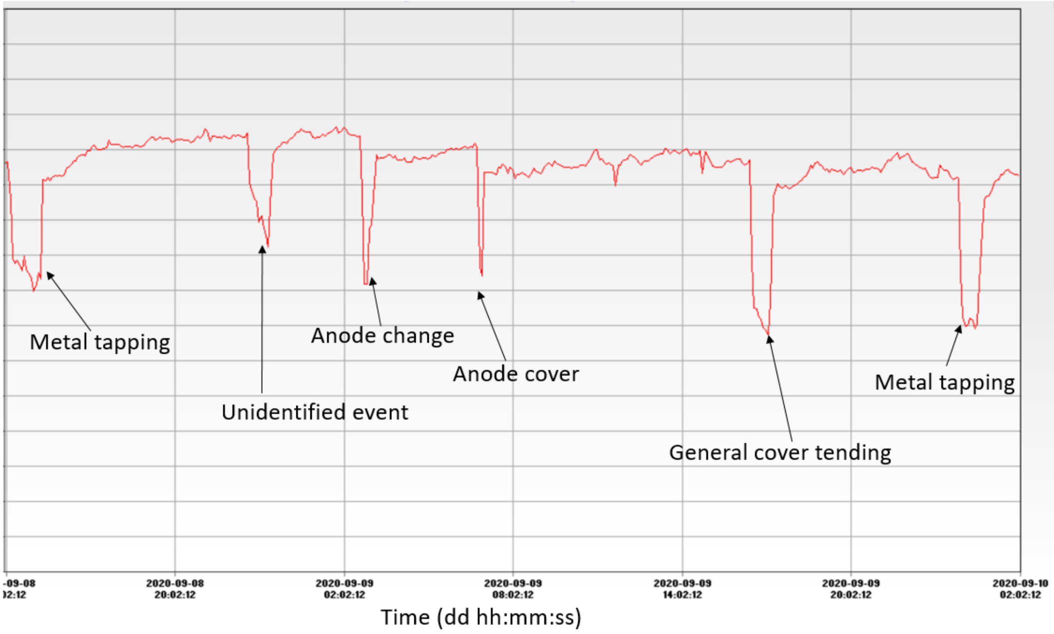

Figure 10. Pot gas temperature and associated events.

4.4. Anode Beam Position

Beam position sensors have been installed on all the pots at the Jonquière AP60 plant. The measurements are used to analyse abnormal situations related to metal tapping and beam raising (see Figure 11).

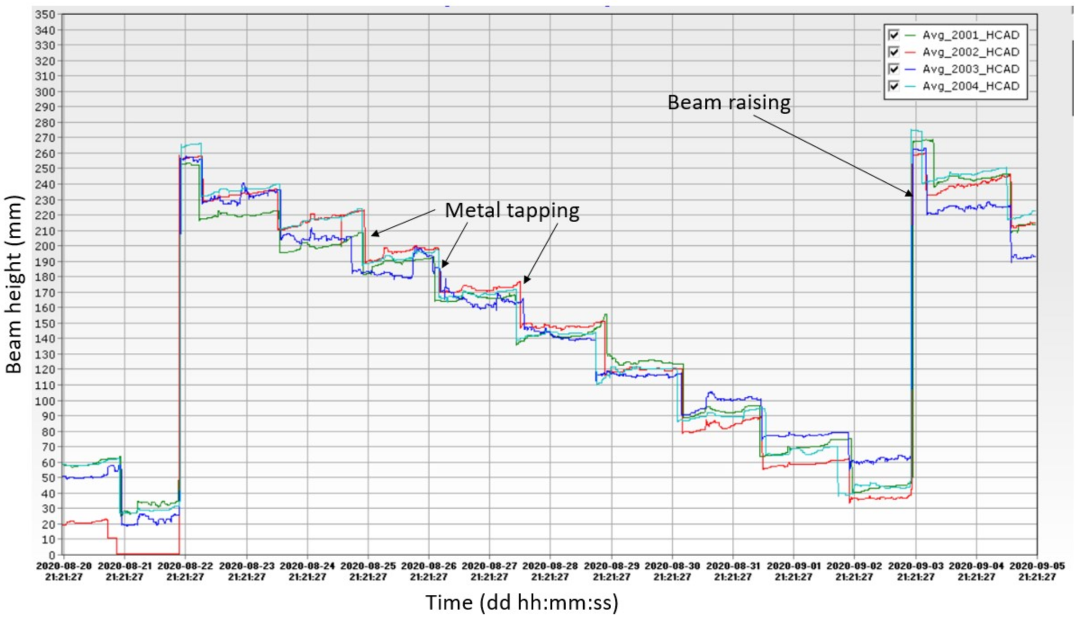

Figure 11. Variation in anode beam position for four typical pots.

4.5. Anode Current Monitoring

In 2001, an anode current monitoring system was developed for the P155 prototype cells at the Grande-Baie smelter (Figure 12).

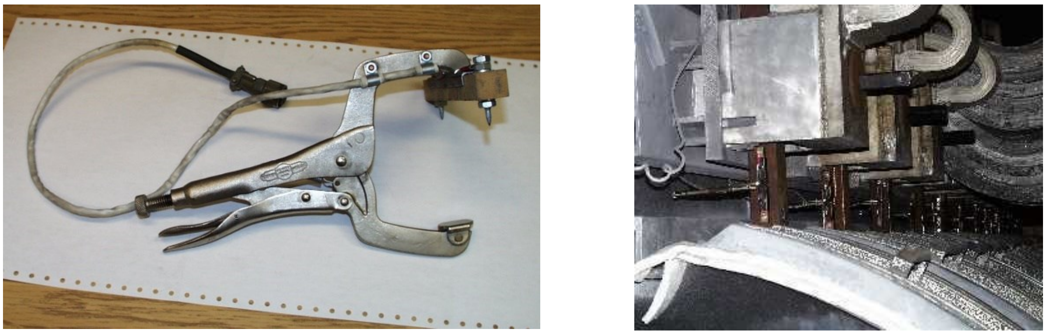

Figure 12. Prototype continuous anode current measurement system. Left: sensor prototype, Right: installation on a P155 cell at the Grande-Baie smelter.

The system has greatly evolved since then and has been working satisfactorily since 2017 and is now deployed on the 38 AP60 pots at Jonquière. Figure 13 shows an example of data collected to monitor cell instability problems after tapping.

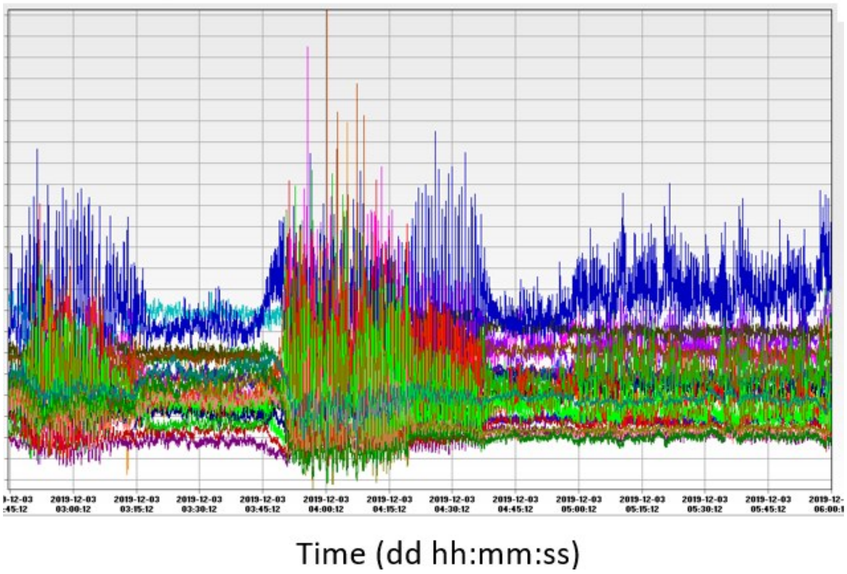

Figure 13. Evolution of individual anode currents at Jonquière smelter.

5. Algorithms

5.1. Continuous Monitoring of Pot Gas Temperature to Follow-up Pot Operations

The Rio Tinto research and development team has been working for several years on tools and algorithms aiming at the continuous monitoring and analysis of individual pot gas temperature [5]. The first objective of these developments is to measure the amount of time for which pots are open (either tapping doors or hoods) during pot operations and inform operation teams of any problems, as this is related to the efficiency of pot gas collection and hence environmental performance. As Rio Tinto smelters have several different cell technologies, it was necessary to develop dedicated algorithms in order to achieve good detection performance for each one of them. These algorithms have been developed with the following objectives:

- Not detecting false positives on opening (no detection of opening when there is none);
- Making sure to detect every closure, even if false positive (in the worst case, accepting closure detection even if the pot is still open).

It is quite a challenge to be able to detect every single pot opening and closing for all cell technologies, as can be seen in the case of the AP60 (Figure 14). In this case detection is excellent, with 91 % open time detected.

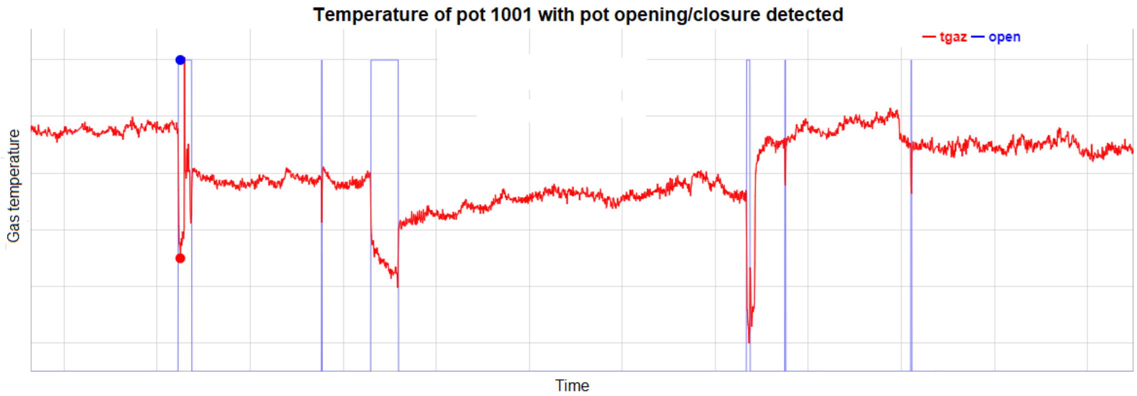

Figure 14. Detection of opening and closing of an AP-60 pot.

Many exceptions and different gas temperature trends have to be managed by the algorithms, to be sure of never concluding that the pot is open when it really is closed. Given these limitations, a target of detecting 85 % of pot opening time is deemed acceptable when compared with present results at a low frequency of inspection. In the past few years, similar algorithms have been developed for the P155, AP40 and AP60 cell technologies. Pot opening detection results for the different technologies are shown in Table 1.

Table 1. Pot opening detection performance for different pot technologies, (%).

Cell technology	Pot hoods	Tapping doors
AP40	86	
AP60	92	62
P155	92	90

Observations were made in 2020 to confirm the results for the AP60. These showed that the way tapping is carried out significantly affects the pattern and extent of gas temperature change. The position of the tapping crucible muffler has a notable effect because it influences the return of hot gases from the crucible to the pot. The AP60 algorithm will be adjusted first to allow for such influences (because of its poor performance), followed by those for the AP40 and the P155.

In the near future this system for continuous automated monitoring of these pot operations and their effect on pot gas emissions will form an important part of Smelter 4.0, improving pot gas collection and thereby our environmental performance.

5.2. Polarization Detection and Feeding Strategy

Polarization – *i.e.*, a low voltage anode effect – is detected using a model that analyses anode current drops, as illustrated in Figure 15. The model was developed using CF_4 measurements (> 200 ppb) on one pot over a three-month period, for a total of about seventy polarizations.

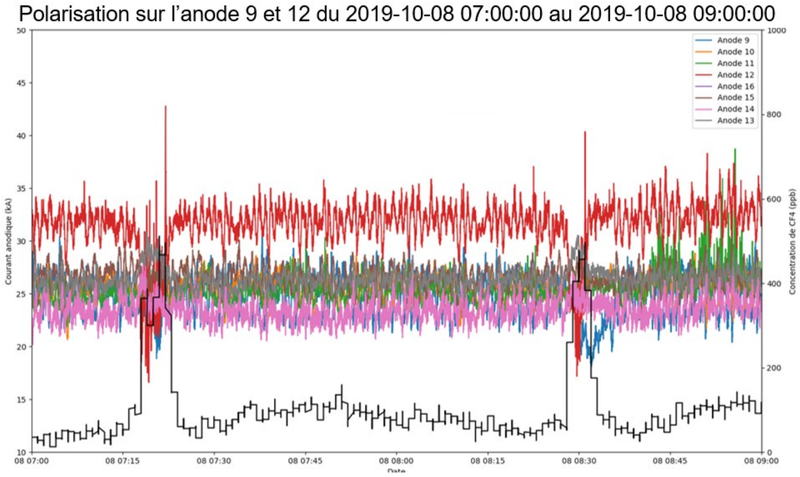

Figure 15. Anode currents for eight anodes over two hours of operation, showing polarization detection in two of them.

The correlation between the frequency of polarization for each anode and its relative position with respect to the different point feeders was studied. These results were analysed in order to optimize alumina feeding strategy for each individual feeder.

5.3. Improvement in Anode Setting

As a result of analysing the huge mass of available data, the normal pattern of current pickup in newly changed anodes has been defined. On this basis, a strategy has been developed in order to detect bad anode positioning and an operational interface designed that enables the operator to make corrective adjustments when required.

Figure 16 illustrates a typical case. The anode current rises more sharply than expected (upper graph), and the algorithm calculates a high probability (lower graph) that the anode is set too low. The system then sends a message to the operator, who raises the anode somewhat to reduce its share of the current, bringing it into line with the normal profile.

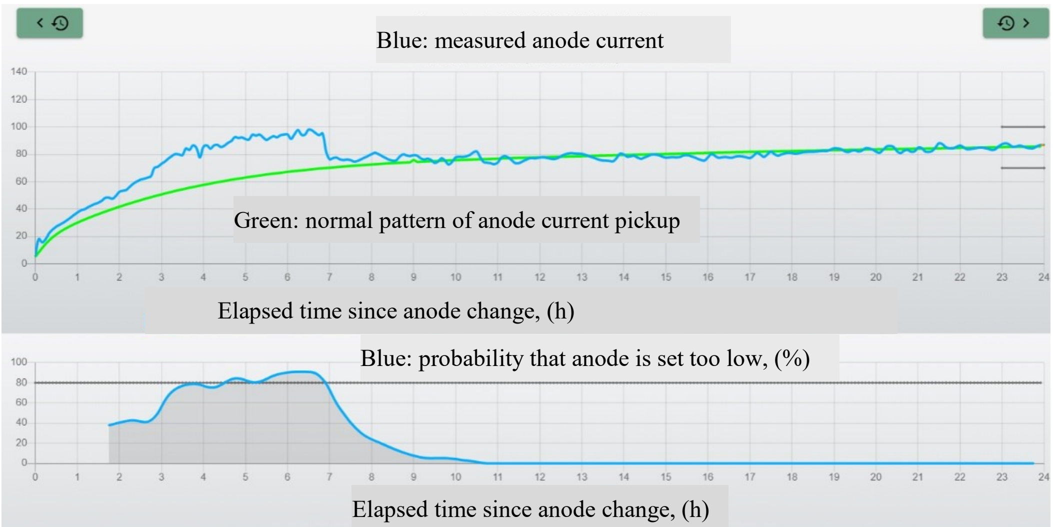

Figure 16. Anode low setting detection. Top: measured and normal patterns of anode current pickup (%), Bottom: probability of low anode setting (%).

6. Conclusions

Significant progress has been made towards Smelter 4.0. Each pot is equipped with sensors giving information which is used automatically to improve the performance of that particular pot, the algorithms adjusting the response to suit its specific characteristics. All relevant information can be easily accessed anywhere by operators and managers, enabling them to take better decisions. This is only the beginning, because technology evolves quickly and opens new opportunities for the aluminium industry to face the coming challenges. The most important of these challenges is a consequence of climate change: better management of energy consumption, which will oblige smelters to be more flexible in adjusting their power levels. As Rio Tinto sees it, Digital Twinning will be instrumental in bringing about this revolution.

7. References

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