Millivolt Anodes and Cicero - new tools for better pot and potline control

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Abstract

Uniform anode current distribution is the basis of stable pot operation and best pot performance. The most common method to control the anode current distribution is to measure voltage drop between two points on each anode rod, the so called anode millivolt (mV) drop, with a fork. In order to make this measurement more reliable, rapid and automatic, Maestria Solutions, in collaboration with Rio Tinto, has developed Millivolt Anodes (mVa) tool, including a lightweight fork, automatic recording of the anode mV, pre-programmed sequence of measurements and automatic modern data transfer to the computer. This tool has been in use in several smelters, in some for over 25 years in its version using Microflex computer. Another Maestria development is Cicero, a smart vocal annunciation system for potrooms, which broadcasts in different ways (audio, SMS, e-mail, display) relevant messages coming from pot control system. Cicero has also been used in several smelters for years. In this paper, mVa and Cicero will be presented and their features, benefits and advantages will be discussed. Actual results of the most recent versions of these tools will be shown, in collaboration with smelters who are currently testing them and a live demo will be shown.

Keywords: Anode current distribution measurement; mVa; anode setting; potroom annunciation system; potroom alarms.

1. Introduction

There are a significant number of new technologies that can be of great help for aluminium smelter. Often these solutions are the results of continuous work for improvement over many years. Some are kept for internal use only because they are seen for some time as proprietary; however it may happen that they become a spinoff product and made available for distribution on the open market. This is also the case with Millivolt Anodes (mVa). Such technologies attract particular attention if they improve safety and security and also help gaining operational advantage.

In this paper, we present two technologies that have evolved through years and have been used in many smelters worldwide designed specifically for use in aluminium smelters. These are:

1) mVa (Millivolt Anodes), which is used to determine anode current distribution from the measured voltage drop between two points on each anode rod, the so called anode millivolt (mV) drop and
2) CICERO, a smart vocal annunciation system for potrooms, which broadcasts in different ways (audio, SMS, e-mail, display) relevant messages coming from pot control system.

2. mVa, a smart anode current distribution control solution

2.1. Anode current distribution and anode setting

The factors affecting the cell behaviour come from many sources. The cell parameters are linked in such a complex way that the best setting to apply to each cell is not obvious. For example, the change in cell temperature can be attributed to any of the following parameters: cell voltage, cell current, feed cycle, alumina concentration, depth of metal pad, ledge formation, frequency and duration of anode effects, amount of alumina covering over the anodes, metal tapping, anode change, cell instability, etc. Deviations from normal operation have to be detected and an indication given what might be the source of the deviation; this is the first logical step to cure the problem.

Uniform anode current distribution is the basis of stable pot operation and best pot performance. Some people consider that 80 % of pot operation problems are caused by anodes. Even though this certainly is an exaggeration, it is well known that the anodes are often a source of potential problems. It is therefore logical to monitor closely the anode behaviour in order to find and correct any irregularity early.

Specifically, anode setting certainly disturbs the cell operation for several hours after setting if not several days.

The anodes are set to a certain target height with respect to the old anode butt for proper operation of the cell. Anode setting accuracy in typical operational condition is influenced by many factors. Even in the best situation, it is quite common to have some margin of error in the actual height adjustment. Operators have typically found the following pattern, explained in [1]:
Anode set too low has the following consequences:

- High current flow in this anode
- Prone to cracking carbon, causes bad connection in cast iron-carbon contact
- Early instability as metal waves increase, higher noise,
- Computer adds resistance modifiers,
- Detrimental to current efficiency, reduces aluminium production.

Anode set too high has the following consequences:

- Low current flow in this anode,
- Longer time to heat up,
- Local bath freezing, side ridge formation under the anode,
- Risk of setting anode on side freeze with down bridge moves,
- Current increase in the other anodes, instability, noise,
- Resistance modifiers added.

2.2. Development of Microflex anode mV system

At the beginning of the nineteen eighties, one well known company in the aluminium world, Aluminium Company of Canada (Alcan), began to work on an efficient way to detect this kind of problem in actual production situations, not just for test or research purpose. What was to be found needed also cost to benefit evaluation, if the solution was to be implemented in a large scale aluminium smelter or even spread to most of its smelters. It is good to recall that Alcan was for some time, the second largest primary aluminium producer in the world with several smelters in the Saguenay region of Quebec, Canada. Also the Arvida Research and Development Center (ARDC), still operating now as part of Rio Tinto, was a very active research branch of Alcan, which supported development of new solutions in improving everything to do with aluminium production in the associated smelters.

It is well known that anode current distribution measurement is an important issue and the most common and the simplest method is to measure millivolt drop on all anodes using a voltmeter and a fork with two pins at specified distance between them. The pins are applied to the anode rod to take the voltage drop, which is proportional to the current flowing in each anode.

This method has been used by most smelters since many decades. The frequency of measurements varies in smelters and for different cell technologies. The accuracy depends on the operators and most often it is considered to be an “on the spot” quality check for anode setting or for finding problem anodes in problem pots. The actual measured values are not necessarily communicated to process control or to some post-validation review, or not really systematically noted or written down and entered into the computer. Moreover, typically the outcome relies on human decision “on the spot”, whether the cell is in normal or abnormal state. In many cases the problems were not correctly identified. On the other hand, in smelters where the anode mV measurements were systematic and recorded, more manpower was required.

The real lack of accuracy and the unsystematic nature of the application of this procedure were the first targets for improvement. The measurement had to be systematic, easy, error free, mobile and a one man operation, while reducing human induced errors in the process.

At that time a new class of portable computers, called Personal Data Computers, appeared on the market. In this category, a particularly rugged model for rough and dusty industrial environment, called Microflex, was available and manufactured in Quebec. Tests showed that this portable computer was well suited for potline environment. A new hardware module was added for analogue to digital conversion of the millivolt signals and easy data transfer from Microflex to the office computer. Software was developed for pot configuration in the potroom and for anode configuration in each pot as well as for the analysis in the office computer. This was the beginning of the Microflex for anode mV measurements, shown in Figure 1 in plant use. The system had full potline and anode configuration for data recording on each pot depending on cell technologies and potline arrangement. The data were transferred to the computer via a serial cable connection (RS-232 in the early release and Ethernet later).

The anode mV fork was already light in the early release, but later it was made ultra-light, typically up to a few kilograms depending on the length, using composite material. The new equipment was so successful that it was adopted by many smelters over the years. Now, there is a full interface available for the ALPSYS control software, but the open architecture enables an easy transfer to other pot process control systems with minimal work.

Figure 1. Millivolt fork with Microflex Personal Data computer at operator’s waist.

2.3. New version of mVa

The Microflex computer is not supported any more, since the technology is evolving. Now, the computer technology and the communication systems offer new opportunities, which have been implemented in the new mVa system. The role of the personal data computer is now incorporated in the electronics module which is in the handle of the fork as shown in Figure 2. The measurement is shown in Figure 3.

The new version of mVa by Maestria Solutions is made of ultra-light composite material and contains all the electronics for the measurement, display, and control, so this system operates without any computer at operator's waist. As the previous model, the length of the fork and the measurements points spacing can be adjusted for specific cell technologies. A built-in joystick enables to make a selection by the operator of the specific operating mode needed, with the help of the built-in display. A strategically placed pushbutton is used by the operator each time he wants to confirm a good reading on an anode by mVa.

The new mVa uses Bluetooth for communication that enables bi-directional communication with an external device. When doing the actual measurement around the cell, it is not mandatory to be in communication with the computer since the fork stores the data for transfer, when the operator gets back near a computer later on, at the end of the run. It has a battery that can make the system run typically for a few weeks on one charge, depending on the amount of usage in the potroom. Also, three individual Light Emitting Diodes (LEDs) give extra information to guide the operator in determining a normal or abnormal measurement; it even allows seeing if an anode is unstable, using customizable software trigger parameter. This is especially useful after anode change. Another LED gives feedback of a good reading for the operator, confirming that he can proceed to the next anode. A trained operator can easily do one cell in less than one minute.

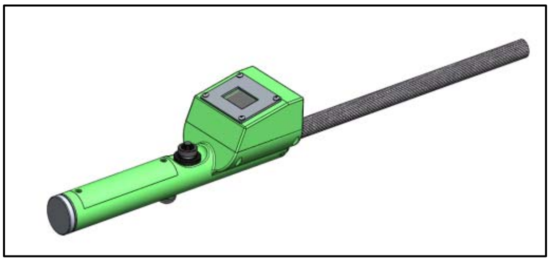

Figure 2. New mVa handle with electronics module and display.

Figure 3. Use of the new mVa.

An algorithm in the mobile mVa instrument enables quick detection of abnormal anode behaviour giving the operator a more systematic detection of abnormal situation. The new version of the mVa, will include a very sophisticated customizable detection capability that gives the opportunity to adapt the system for each prebake cell technology and to adjust specific criteria corresponding to the desired targets. Also, there is a software function that enables a quick recheck of an anode measurement, to make sure the system actually detects really an abnormal anode and not some transient value, generated by the perturbation in the pot or potline. So, the system re-acquires (rechecks) the measurement.

2.4. Improving anode change quality with the control of mV anode voltage drop

As an example, the measurements made for anode change quality control are presented. For pot Anode change is one of the most disturbing operations for the pot; it may:

- Create pot instability,

- Cause alumina feeding problems with alumina coming from crust,
- Produce thermal shock and break off part of the anode, reducing active anode surface,
- Create sludge on the cathode,
- Change the quality of anode current distribution.

As a standard procedure in most smelters to control the quality of anode changed is anode rod mV measurement, 24 hours after setting. If a regular digital voltmeter and a regular fork are used, this amounts to a large scale procedure for the smelter as it has to be carried out on all pots for all anode changes.

This operation gives a quick rough estimate of the quality of the anode setting and of the actual condition in the pot when the measurement is made. But, if the control measurement is done on unstable pot, the action following the measurement could be wrong. Also, the human factor adds to the uncertainty of this procedure, heat and overstrain can also play in this process.

The systematic mV measurements of all anodes of the pot with Microflex or with it upgraded version mVa, opens new possibilities and new metrics for the control of anode setting quality, such as:.

- Compare 24 h mV on changed anode to mV of all other anodes for each pot,
- Compare mV from team to team,
- Compare mV per operator.

Table 1 below, gives an example of the analysis done easily when using this system.

Table 1. Analysis of all anode mV, compared to new anodes at 24 h.

Date install	Sector	Team	CV 24 h mV excl. others*	Difference CV 24 h -CVC**	Average
2015-07-08 19:00	100S	C1	15.9	4.7	7.7
2015-07-08 19:00	200N	C1	28.23	10.8	
2015-07-08 19:00	400S	C2	17.79	3.5	5.8
2015-07-08 19:00	500N	C2	19.89	8.0	
2015-07-09 7:00	200S	B1	20.74	7.4	10.6
2015-07-09 7:00	300N	B1	28.72	13.8	
2015-07-09 7:00	500S	B2	36.88	10.2	5.9
2015-07-09 7:00	600N	B2	14.22	1.7	

* CV 24 h mV excl. others - is the coefficient of variation of the 24 mV anodes which excludes the corner anodes and the anodes in front of a feeder.

** Difference CV 24 h-CVC is the difference between the coefficient of variation of the 24h mV anodes and the coefficient of variation of the mV of all the anodes.

The coefficient of variation (CV) is defined as the ratio between the standard deviation and the average:

$$CV\ (\%) = \text{standard deviation} / \text{average} * 100$$

It is possible to follow the results per team, per operator, per pot or per potline and to analyse relations between the coefficient of variation of the 24 h mV and the coefficient of variation of the anodes mV with other parameters. The results are used to improve anode setting quality. To make this step more effectively in a day to day routine, a process historian database analysis software from Maestria Solutions is running on PC and is part of the mVa system. This helps identifying the problems of anode setting and improves the quality of setting. Very significant improvements can be achieved.

Rio Tinto (RT) uses this method in many of their smelters as a continuation of the system installed previously by Alcan. Figure 4 shows current efficiency improvement associated with this method in one smelter with P155 cell technology during approximately one year. In this period of application, systematic measurements of anode mV with mVa improved current efficiency very significantly, by about 1.5 %.

In Figure 4, the out of range value near 95 % is associated with another process change not linked to the method as reported by RT. It can be seen clearly that as the coefficient de variation becomes smaller on the potline, the current efficiency gets better.

Also the same methodology and equipment is used in AP-30 (AP-3X technology family) in Alma smelter. Figure 5 shows also the same pattern of improvement, but the values are slightly lower.

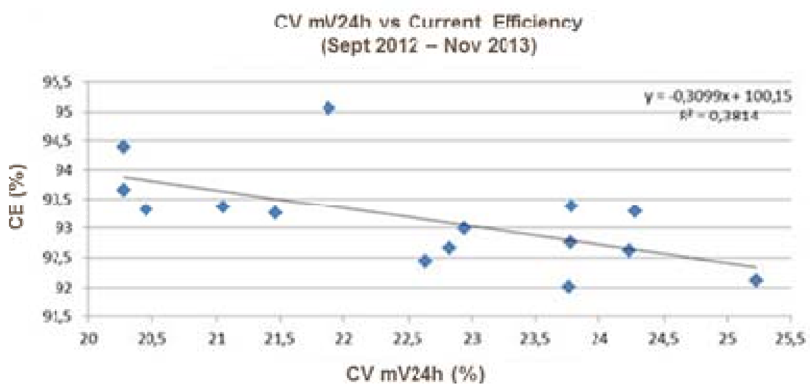

Figure 4. Coefficient of Variation of the 24 h mV vs Current Efficiency, P-155 smelter, September 2012 to November 2013.

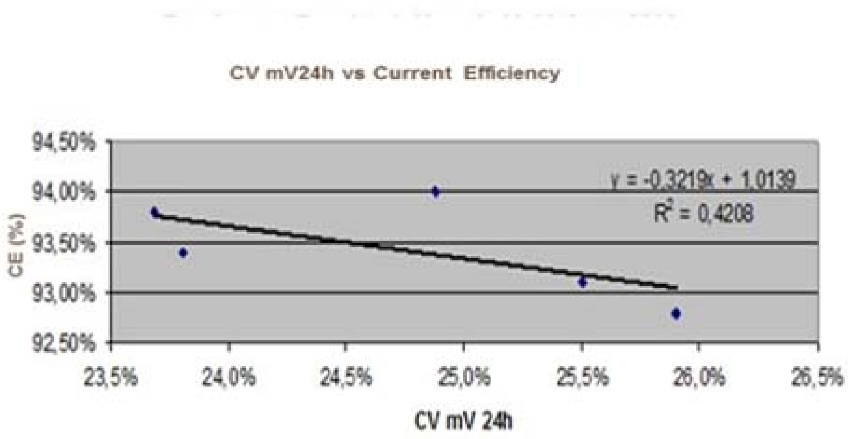

Figure 5. Current efficiency vs. coefficient of variation mV 24 h Alma smelter, May to Sept 2009.

It is interesting also to mention that for those two smelters, and in fact most of the plants using the equipment and the method associated, the mVa is part of the normal reduction operation, in order to keep current efficiency the highest possible.

It is easy to see a very interesting cost to benefit of the system in a smelter. Moreover, this demonstrates that the overall approach is not designed to just one prebake cell technology but can be easily adapted to many others.

Table 2 gives summary of a typical measurement campaign. These data are from the Grande-Baie smelter using P155 technology.

Table 2. Summary of a measurement campaign in Grande Baie smelter.

Measurement campaign / Grande-Baie/ P155		
Parameters	**Value**	**Remark**
Amperage (kA)	205.5	Alcoa P155 cell
Total number of cells controlled	192	
Anode rods per cell	24	
Period covered by the campaign (hours)	36	3 shifts of 12 hours
Measurements, including recheck	4683	Recheck is done when a potential abnormal measurement is recorded
Measurements without recheck	4608	
Rechecks	75	Measurements redone
% of rechecks	1.63	% of measurements redone
Measurement mean with rechecks (mV)	6.54	Mean
Standard deviation of measurements with recheck (mV)	4.59	Standard deviation
Measurement mean without rechecks (mV)	6.46	Mean
Standard deviation of measurements without recheck (mV)	4.03	Standard deviation
Average time for 1 pot measurement (s)	48	Typical value for 1 cell
Minimum time by cell (s)	33	Frequently the same value for many cells
Mean time to mesure 1 anode (s)	2	
Mean time to mesure 32 cells (mm:ss)	26:44	This is for 6 groups of 32 cells
Mean time for 1 cell including cell to cell move (s)	50	

With all the data available for the evolution of the mV drop for each anode in the database through time, it is also possible to make other analyses. RT uses the system in some of their smelters to evaluate anode consumption. This makes possible to simplify the determination of the anode setting height target in comparison to the old anode.

Using this equipment also reduces the overall workload for anode change and makes the anode changing equipment (pot tending machine) more available, which is very useful in case of amperage increase on an older potline. Also, there is less time of exposure of workers and thus better health and safety benefits; the ultra-light design allows quick operation and reduces exposure.

Another application can be made for corrections of anode adjustments with respect to metal curvature, especially in cells with low anode-to-cathode distance (ACD). It is beyond the scope of this paper to go in detail on these topics.

3. CICERO, a smart vocal annunciation system for potrooms

Another Maestria development is Cicero, a smart vocal annunciation system for potrooms, which broadcasts in different way relevant messages coming from pot control system. The system can carry in the plant not just alarm messages, but also inform on any operational situation that just requires the attention of some workers in the plant.

Like mVa, CICERO emerges from the work done in some Alcan smelter in the nineteen eighties. At that time, a review was done on available technology, see Table 3.

Table 3. Alarm technology review

Alarm types	Advantages	Disadvantages	Action delay
Lamps and horns	Simple	Need to see the lamps No information for unusual alarms	Low to High
Pagers, Cell	Complete information	Need to look at for more information Must wear it	Low
Speech	Complete information No action necessary	Unusable in noisy environment Investment cost was higher in the past	Lowest
Billboard or screen	Complete information Usable in noisy environment	Need to look at No wake up	High

We need two important features to make this kind of system really usable on a continuous basis. Number one is to make the system only broadcast relevant messages that make the staff in the plant aware of significant messages, and number two, make this process automatic, so that no direct human intervention needs to be made. This system must work continuously by itself 24 hours a day, 365 days a year. These two features are really the foundation for the design of such a system.

The system is connected to the process control system in real time, so it is possible to get every operating situation evaluated by the system. But to make the system really effective and not to spread any non-critical information through the plant floor for each new event, a step is required to check the relevance of the situation, and attach to it some priority. In real operating situation, some unstable situation on the potline could trigger a lot of alarms. Process staff generally has short term intervention to do in this situation, so we need a way to configure the vocal annunciation system to handle the situation correctly.

It is difficult to measure the action delays, but they can sometimes make a difference between unexpected loss or not a loss of a pot. It can make a huge difference for a potline in case of critical unusual alarms. As a typical case, the lowest delays help reducing manually treated anode effect duration and greenhouse gases. Reducing thermal stress due to prolonged anode effects also helps extending pot life.

The system is actually used in many plants worldwide in Canada, USA and Saudi Arabia. There is a full interface available for the ALPSYS control software. The system uses an open architecture and makes the interfacing with other similar systems easy.

Another great feature of CICERO, is that the system is multi-lingual. In fact, even in the same plant, messages can be broadcast in many languages. The message can be extracted from pre-recorded words from a human voice, or can use synthetic voice. The backbone architecture of CICERO is shown in Figure 6. Many outputs can be selected for destination of the message, audio through Public Address System (speaker system), SMS, e-mail, sign display as shown in Figure 7. A regular PC, with a software module design for compatibility with CICERO, can also be used as audio output, so any person can hear the message through their own computer and speakers on their desk. One of the new features available covers the broadcast of audio via Wi-Fi. A compatible Wi-Fi Amplifier box is available that gives the option of having the equivalent of a PAS (Public Address System) without having to install audio cable and avoid having the cumbersome process to route cables through a large plant, greatly reducing cost associated with that work.

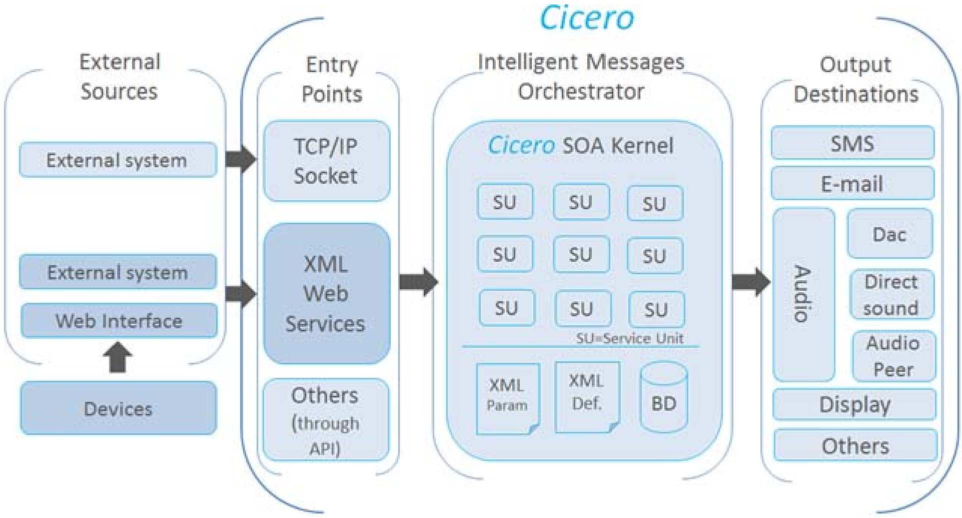

Figure 6. CICERO Architecture

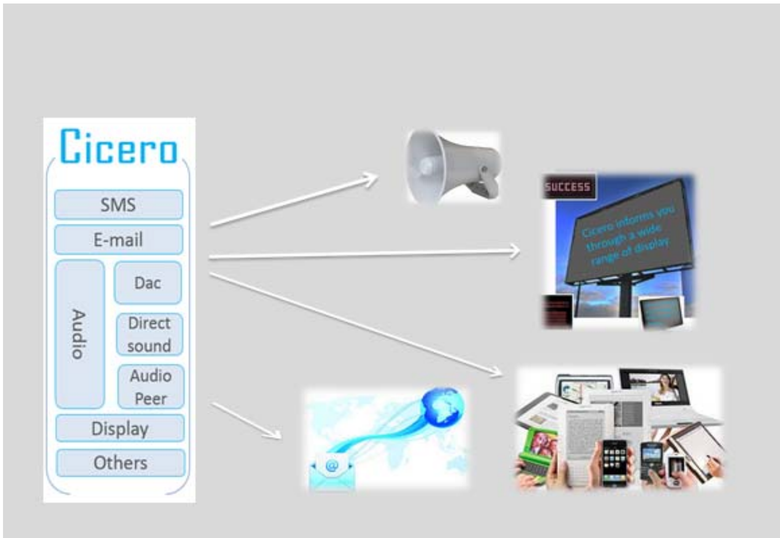

Figure 7. CICERO output device

4. Conclusions

For mVa, the operation gain and increase of current efficiency confirms that the system offers a very good solution for better anode control in an aluminium smelter. Any abnormal or even potential faulty situation can be detected early. The new version with the built-in sophisticated electronics and software can be also closely adjusted for each smelter technology. For CICERO, the system does exactly what was designed for and has been operating very well since many years in many smelters worldwide. Operators gain increased situation awareness in their plant. With the new open architecture implemented, connection to external system will be facilitated.

5. Reference

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