Light Metals 2014
Edited by: John Grandfield
TMS (The Minerals, Metals & Materials Society), 2014

ON-LINE MONITORING OF ANODE CURRENTS: EXPERIENCE AT TRIMET

Andreas Lützerath[1], James W. Evans[2] and Ron Victor[2]
[1]TRIMET Aluminium SE, Niederlassung Hamburg, Aluminiumstraße, 21129 Hamburg, Germany
[2]Wireless Industrial Technologies (WIT), 4096 Piedmont Ave. #193, Oakland, CA 94611, USA

Keywords: Hall-Héroult cells, anode current monitoring, anode effects, current efficiency

Abstract

Since early 2012, individual anode currents of one Hall-Héroult pot at TRIMET, Hamburg, have been monitored using a system that measures the currents by sensing the magnetic fields produced by the anode currents. The system reports all anode currents every second, as well as the pot voltage. Data are transmitted wirelessly from the pot to a receiving computer near the pot for processing and onward transmission to the TRIMET network as well as to WIT in California. Interactive real-time plots of individual anode currents are available to engineers and others at both locations. The paper summarizes the difficulties overcome in the initial stages of the installation and displays representative plots of currents before and during anode effects, after anode changes, current interruptions etc. Some thoughts are provided on the value of making individual anode current measurements.

Introduction

During the week of January 23rd, 2012, a system was installed on one pot, at TRIMET's Hamburg smelter, to monitor the currents in all anode hangers every second. This was a system from Wireless Industrial Technologies (WIT) that has been described in previous Light Metals[1] and elsewhere [2]. Briefly, the system relies on measurement of the magnetic field produced by each anode current. The fields are picked up by multiple sensors that are on circuit boards ('slaves') that are positioned inside an insulated stainless steel enclosure mounted behind each anode hanger; see Fig. 1. The multiple sensors permit minimization of 'cross-talk' from other anodes and other conductors (e.g. risers) that would otherwise corrupt the measurements of a particular anode. Further minimization of crosstalk can be done using a mathematical model [3]. Slaves are 'daisy-chained' along one cable to a 'master' circuit that sits at the end of the pot. The master is connected to pot voltage to provide power and so that this voltage too can be measured by the system. Power flows along the cable from the master to the slaves and the cable is also the conduit for transfer of data from slaves to master. There is one master on each side of the pot and the data are relayed wirelessly from the master to a 'manager' which is an industrial computer in the potroom that receives the data and does routine chores, such as attaching a timestamp before sending the data via the internet to Amazon Web Services (AWS) for archiving and processing by WIT so that data and plots are immediately available to TRIMET personnel anywhere. The system can be used for monitoring pots, or ultimately for control. The system was upgraded in February, 2013.

The principal objective in installing the system was to see if early warnings of anode effects, reported by Tarcy and Taberaux [4] for pots with pair-controlled anodes, could also be seen in pots at TRIMET, which are of the more normal design with anode hangers attached directly to the anode bus. However, it was also anticipated that the measurements would show other phenomena of practical interest such as the pick-up of current following an anode change, anode spikes, any poor distribution of current among the anodes (likely to cause loss of current efficiency) and pot instability. Indeed AEs are comparatively rare at Hamburg; that fact, combined with the current low carbon price, make these additional results quite interesting.

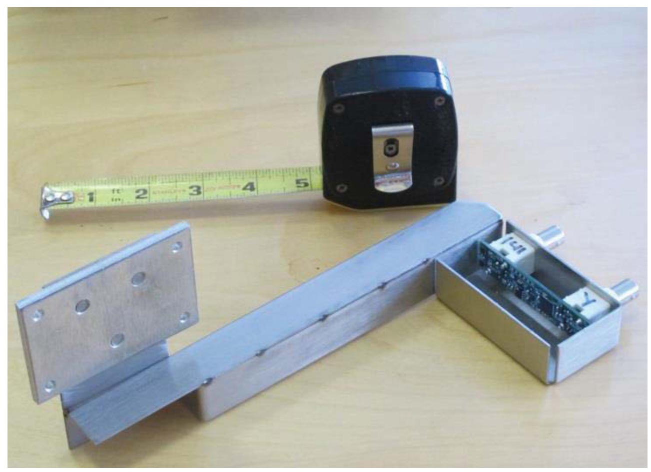

Figure 1: A "slave" (to the right of the photo) mounted within its enclosure. The flange on the left is attached to the bus and the reinforced "arm", to the right of the flange, places the slave behind an anode rod. Photograph before the slave is insulated.

Results

The main difficulty encountered initially was the modifying of the Hamburg firewall to allow communication between the manager and AWS. That communication is two-way, so that the manager firmware can be modified and even slave sensitivities selected, from California.

No mechanical damaged was experienced by masters and slaves except that, for the initial 2012 installation, some enclosures became bent, displacing the slaves from the correct position. One of the 18 slaves was not functioning after one year, probably as a consequence of being overheated. These slaves and enclosures were replaced in February, 2013, by ones where the 'arm' of the enclosure was reinforced - see Fig. 1 – and the insulation was changed for a better one. The replaced slaves were returned to WIT where they were recalibrated for comparison with their earlier calibration - by placing in the field of a DC electromagnet (itself calibrated against a gaussmeter) – prior to shipment to TRIMET. Thirty-four sensors were tested in this way; the (absolute) change between sensor output from January, 2012 to June, 2013 averaged 2.2% indicating that the slaves are robust in the hostile environment of an aluminum pot.

Fig. 2 is a plot of the file size stored at AWS for each day's data. [It is emphasized that the data are transmitted every second but stored in daily 'bins' (which are accessible throughout the day).] For a correctly working system there should be ~32MB of data per day (three field values and a temperature for each slave, plus master temperatures and pot voltage and the timestamp, every second). Clearly the system has been functioning most of the days since the upgrade in February, 2013. A firmware upgrade in mid-2013 enabled a further improvement in system robustness.

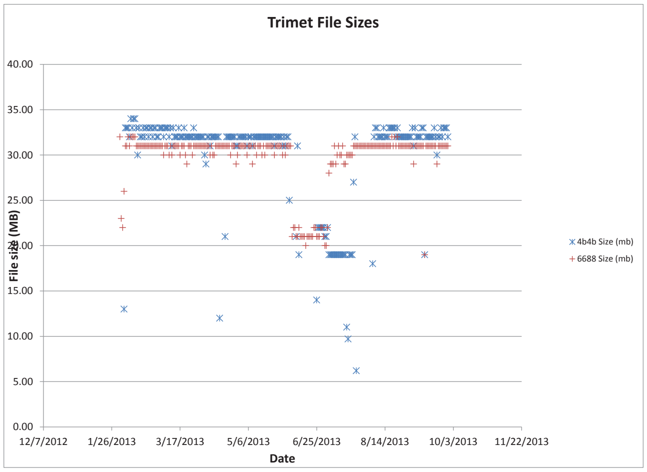

Figure 2. File sizes of data from TRIMET for much of 2013. Full transmission of data corresponds to a file size of ~ 32MB

Fig. 3 is a screenshot of the 'dashboard' which is accessible to personnel at TRIMET (but password protected) via the internet. The plot is for a period on September 29th when an anode effect occurred. The horizontal axis is time in h:m:s. The magnetic fields – surrogates for anode currents – for all nine anodes on this side of the pot, plus pot voltage, are part of the dashboard. The current of anode # 12 is seen to start diminishing about 35 minutes before the rapid rise in pot voltage characterizing the AE. This mirrors the early warnings of AEs reported previously from anode current measurements at other smelters. [1] [4]. This 35 minute early warning of an AE is exceptional in that most warnings were of the order of a few tens of seconds.

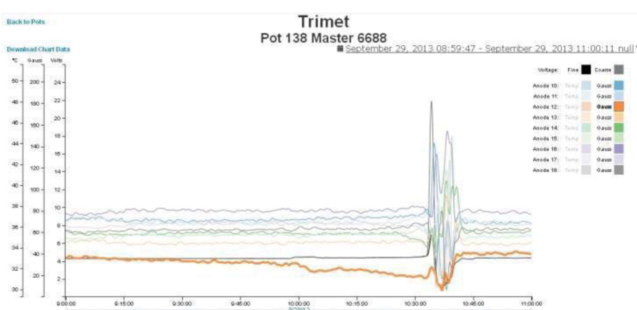

Figure 3.Screenshot of dashboard showing anode currents redistributing prior the rise of pot voltage characterizing an anode effect on September 29th, 2013. . The horizontal axis is in hours, minutes and seconds.

Fig. 4 (using an earlier version of the dashboard) shows the sinusoidal variation in field (again as indicative of anode current) for a condition when the pot is unstable. Note the long period, about 35 seconds, corresponding to the passage of a surface wave along the bath – metal interface. The waves are not in phase because a peak in the interface under one anode is at a time when that interface is lower (or lowest) under other anodes.

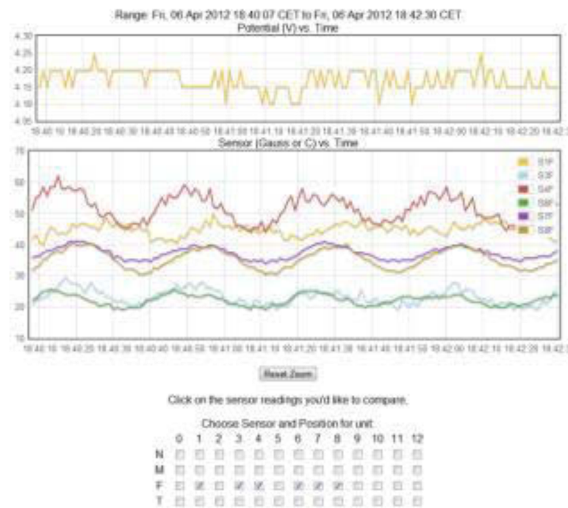

Figure 4.Sinusoidal fluctuation in anode currents due to pot instability, as detected by the WIT system.

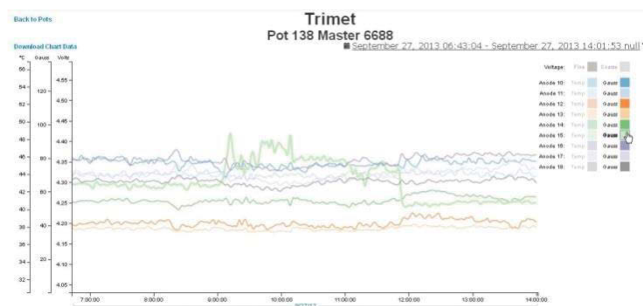

Figure 5.The effect of lowering one anode (#15) for three hours around 9:00 on September 27th.

Fig. 5 shows the magnetic field traces for a period on September 27th when one anode was lowered for approximately three hours. The increase of current at about 9:00 has the effect on field that is obvious in the figure. The lowering of the anode appears to have induced some instability in the pot which decayed after approximately one hour. The readjustment of the anode position around 12:00 is also obvious in the figure.

Fig. 6 illustrates the current draw when an anode was changed on October 26th. [Most traces were left out of the figure for clarity.] The anticipated drop in field (therefore current) to near zero as the cold anode is inserted into the pot is evident in this figure.

Figure 6. Development of the anode current (blue line) and pot voltage (black line) following an anode change on Oct. 26th, 2013.

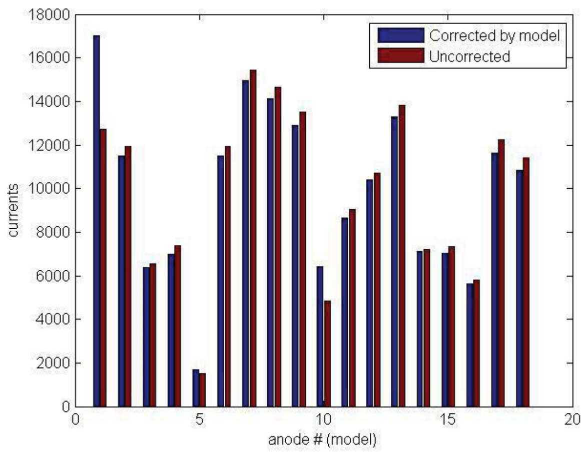

Figure 7. Illustrating the magnitude of the correction provided by the mathematical model.

Fig. 7 shows the results of applying the mathematical model to one second of data. The brown bars are currents calculated by using the assumption that they are proportional to the magnetic fields (of which Figs 3-6 are representative). The blue bars are the results of a more refined computation in which the positions of the important conductors (risers etc) and currents in those conductors are allowed for. It is seen that the model brings about small corrections except for two anodes (model #s 1 and 10); for those anodes the slaves were placed at positions, with respect to their anode hangers, that were significantly different from other slaves and this difference is corrected for in the model.

Comments and Conclusions

Measurement of individual anode currents by magnetic field measurements has proved to be robust, easy to use and informative at TRIMET. Warnings of anode effects, unstable pots, current pick-up after anode change and other phenomena are clearly discernible in the data. All these are visible from any internet connection and raise the possibility of reports and warnings to operators and supervisors by cell phones and other mobile devices. There are other economic variables, such as the effect of anode current distribution on current efficiency, that warrant further examination of the benefits of the system. There is the additional advantage of having a new tool for learning more about the Hall-Héroult pot.

References

[1] J. W. Evans and N. Urata, Wireless and non-contacting measurement of individual anode currents in Hall-Heroult pots; experience and benefits, Light Metals 2012, (Carlos E. Suarez ed., TMs, Warrendale, PA, 2012), pp 939-942

[2] J. W. Evans and N. Urata, Technical and operational benefits of individual anode current monitoring, Proceedings of the 10th Australasian Aluminium Smelting Conference, Launceston, Australia, October, 2011

[3] N. Urata and J. W. Evans, The determination of pot current distribution by measuring magnetic fields, Light Metals 2010, (John A. Johnson ed., TMS, Warrendale, PA, 2010) pp 473-478,

[4] G. Tarcy and A. Taberaux, The initiation, propagation and termination of anode effects in Hall-Heroult Cells, Light Metals 2011 (Stephen J. Lindsay ed., TMS, Warrendale, PA, 2011), pp 329-332