Recent On-line Measurements of Individual Anode Currents at Alouette

James W. Evans[1,], Lukas Dion[2], François Laflamme[3] and Charles-Luc Lagacé[4]
1. Professor Emeritus,
UC, Berkeley, CA, USA
1. President
Wireless Industrial Technologies, Oakland, CA, USA
2. PhD Candidate in Engineering,
Université du Québec à Chicoutimi, Chicoutimi, Québec, Canada
3. Engineer in process control, Development and Technologies
4. Advisor in continuous improvements
Aluminerie Alouette Inc., Sept-Îles, Québec, Canada
Corresponding author: jim.w.evans@gmail.com

Abstract

Since early 2014, Alouette has used a system provided by Wireless Industrial Technologies (WIT) to measure individual anode currents on two pots. The system works by measuring the adjacent magnetic field generated by the current for each anode hanger. This paper summarizes initial difficulties and how they have been overcome. Recent current measurements show good agreement with alternative methods for measuring currents (e.g. mV drop along anode hangers). An algorithm has been developed for discerning an imminent anode effect from changes in the measured magnetic fields due to changes in anode currents. Practical reductions of anode effect frequency, compared to cells of reference, have been achieved by using the results of this algorithm to trigger corrective action through the pot control computer. Some additional potential benefits of anode current measurement are described in the paper.

Keywords: Anode current measurement; Wireless Industrial Technologies; anode effect prediction.

1. Introduction

Electric currents generate magnetic fields and the determination of a current by measurement of its field has been common since at least early in the last century. An example of the application of this principle in Hall-Héroult cells is the 2001 paper by Jim Barclay and Joe Rieg [1]. In the same issue of Light Metals, Jeffrey T. Keniry et al. [2] pointed to the diagnostic opportunities provided by such measurements. For example, anode effects could be detected a minute or so before the usual jump in cell voltage; at that time one or more of the anodes would start to lose current. A more detailed paper on the early detection of imminent anode effects by measurement of anode currents is that of Gary Tarcy and Alton Taberaux [3]. These investigators observed a distribution of the times at which an anode would lose current, ranging from zero to almost ten minutes. For 95 % of the anode effects, the "early warning" of an imminent anode effect was 30 seconds, or more, in advance of the voltage increase, providing sufficient time to prevent the anode effect.

In early 2012 Wireless Industrial Technology (WIT) installed a current measuring system at TRIMET Aluminium SE, Hamburg, Germany and the results were described by Andreas Lützerath et al. [4]. The system measured anode currents by measuring magnetic fields produced by the anode currents and measurements were relayed via the internet to the cloud. Results showed early warnings of anode effects as well as other cell phenomena such as cell instability or the current pick-up experienced by a new anode. As part of that investigation

TRIMET personnel correlated the magnetic fields from anodes with current measurements made by the well-known technique of measuring the mV drop along a known length of anode hanger. For an individual anode there was a very good correlation between the field and mV measurements. However, when comparing between anodes, the relationship between fields and mV's was poor. For example, the anodes displaying the largest mV's were not all the anodes displaying the largest fields. This is now thought to be due to the misalignment of the sensors that measured the magnetic field near each anode rod, a misalignment caused by a sensor enclosure that was not sufficiently robust to prevent bending during cell operations.

A more robust mounting of the sensors was used at a later installation at Nordural, Grundartangi, Iceland. Again, mV measurements on individual anodes were found to correlate with the corresponding magnetic fields. Figure 1 is a comparison between the two types of measurements for all anodes in a campaign conducted in September. At first glance these results were encouraging with a coefficient of determination (R^2) of better than 95%. However, these results were obtained for a large range of currents (including many cases where the anode is a new one that is picking-up current). For a narrower range of current, say in the top right of the figure, the results show a weaker correlation. The implication is that the system would be useful for some purposes (e.g. early warning of anode effects or pick-up of current by a new anode) but not for others (e.g. telling that an anode was badly placed and therefore carrying incorrect current).

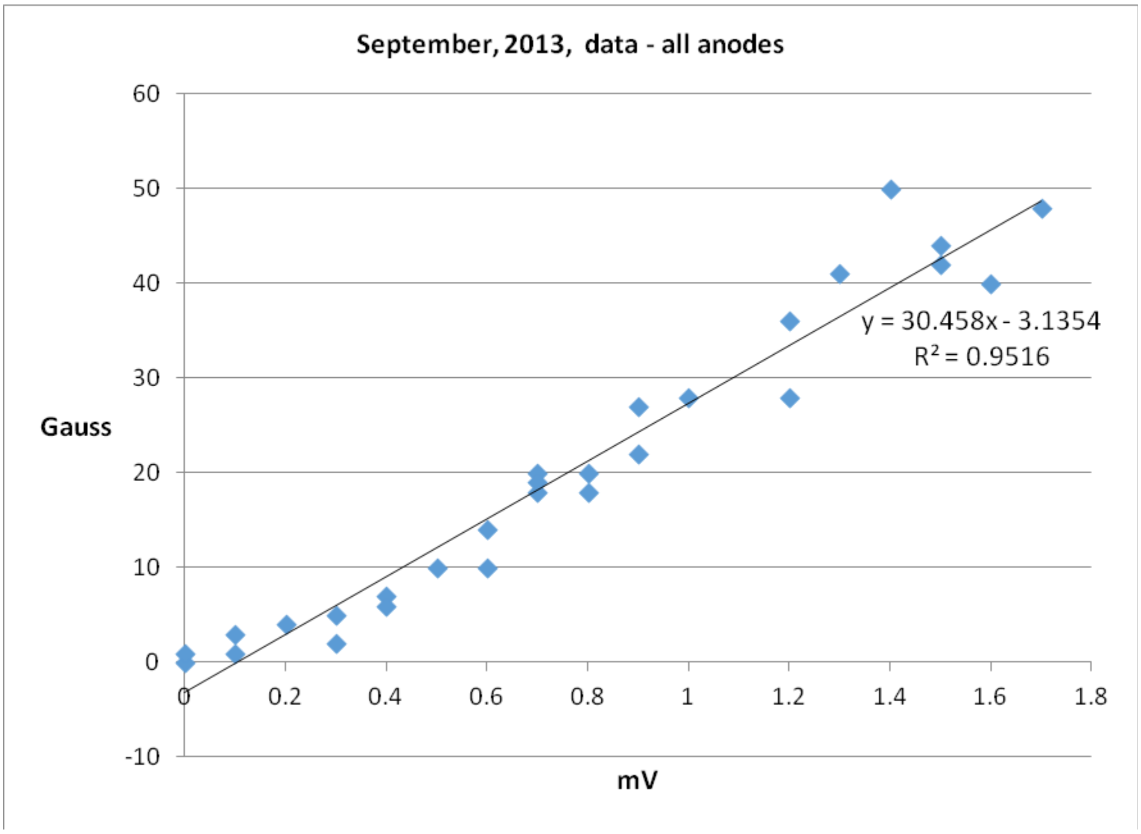

Figure 1. Correlation of magnetic field and mV measurements at Nordural.

In the WIT system the magnetic fields are measured by Hall effect sensors that are mounted on a printed circuit board, along with other electronic components to form a board referred to as a "slave" (as it is controlled by a "master" to which it is connected along with other slaves). The Hall effect sensors give very reproducible signals and are very linear over the magnetic field range of interest. This is seen in Figure 2 where the output from a representative sensor is

3. Conclusions

The WIT system appears to have been impacted by the tilting of the Hall effect sensors on the printed circuits boards (slaves) supplied by the circuit assembly house. Due to this problem, the correlation between individual anode currents from the WIT system and those measured by a clamp-on meter are not as strong in the field as the verification performed under a controlled environment. However, this has no bearing on early warnings of anode effects but impacts other practical results such as the detection of an anode carrying abnormal currents. Future slaves will come from a different circuit house with a mandate to mount the sensors flat on the circuit boards.

Soon after its installation at Alouette, the WIT system allowed early warning detections for most anode effects by detecting the rapid changes in anode currents, reflected in the magnetic fields produced by those currents. Recently those warnings have been fed to the cell control computer, consequently launching a quenching procedure. The preliminary indications are that anode effect frequency, anode effect overvoltage and cell stability improved with these actions.

4. References

1. Jim Barclay and Joe Rieg, Control electrochemical cell dynamics with electrode current measurements, *Light Metals* 2001, 1219-1224
2. Jeffrey T. Keniry et al., Digital processing of anode current signals: an opportunity for improved cell diagnosis and control. *Light Metals* 2001, 1225-1232.
3. Gary Tarcy and Alton Taberaux, The initiation, propagation and termination of anode effects in Hall-Héroult Cells, *Light Metals* 2011, 329-332
4. Andreas Lützerath, James W. Evans and Ron Victor, On-line monitoring of anode currents: experience at Trimet, *Light Metals* 2014, 739-741
5. Lukas Dion et al., On-line monitoring of individual anode currents to understand and improve the process control at Alouette, *Light Metals 2015*, 723-728.
6. Lukas Dion et al., Using artificial neural network to predict low voltage anode effect PFCs at the duct end of an electrolysis cell, *Light Metals* 2016, 545-550. See also a paper by Dion et al. in the September, 2016, Journal of Metals.
7. Nobuo Urata and James W. Evans, The determination of pot current distribution by measuring magnetic fields, *Light Metals* 2010, 473-478,