Validation of Anode Current Distribution Measured by a Smart Individual Anode Monitoring System

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Abstract

Nowadays, larger aluminium reduction cells are constructed with reduced bath-to-anode volume ratios to operate at higher currents and lower anode cathode distance. With aims of increasing production efficiency while lowering energy consumption, the significance of spatial variability in process variables within the cell has intensified. While conventional measurements such as cell voltage and line current fail to depict localised cell conditions, real-time individual anode distribution measurements offer insights into monitoring the spatial dynamics of process variables within the cell. This paper introduces the continuous measurement of anode current distribution through a smart Individual Anode Monitoring (IAM) system. To validate the IAM signals, a comprehensive campaign was conducted involving direct measurements of voltage drop from individual anode rods utilising C-clamps at a designated aluminium smelting cell. This validation process spans one complete anode change cycle, enabling the comparison of anode currents across various operational conditions, including idle shifts, routine manual practices, and other non-routine operations.

Keywords: Anode monitoring, Anode current distribution, Signal calibration and validation, Operational efficiency.

1. Introduction

Monitoring individual anode current signals in the Hall-Héroult cells represents a significant advancement over conventional techniques, greatly enhancing the understanding of localised variations within the electrolysis cell. Traditionally, monitoring frameworks have focused on measuring overall line current and cell voltage [1, 2], providing a snapshot of general cell conditions, such as average alumina concentration. However, these metrics are insufficient for detecting specific localised disparities or operational faults, particularly as the industry shifts towards higher electrical loads.

Technological developments have led to larger anode sizes without a corresponding increase in the volume of molten bath, making the assumption of uniform conditions across the cell increasingly untenable [3]. This mismatch introduces complexities in maintaining consistent cell performance. Additionally, modern practices aimed at reducing energy consumption often involve decreasing the anode-cathode distance in high-current cells. This reduction restricts bath mixture flow, leading to inadequate mixing and uneven property distribution within the cell.

These factors make detailed monitoring of individual anode currents essential for optimal Hall-Héroult cell operation [4-7].

The interaction between anode currents and their specific local environments within a Hall-Héroult cell is both critical and intricate. Each anode-cathode pathway is characterised by distinct bath compositions and temperatures, significantly influencing the distribution of regulated line current among the pathways. This distribution is affected by several key electrical parameters, including local reversible potential, cell overpotentials, and the ohmic potential drop along each path. These factors highlight the complexity of achieving balance and uniformity in cell operation. [8-10] Anode currents not only influence current distribution but also facilitate localised electrolytic reactions and generate ohmic heating within their respective pathways. This activity is crucial for the cell's chemistry and thermal dynamics, impacting overall efficiency and productivity. Measuring these individual currents provides a detailed visualisation of spatial variations within the cell [11-13], allowing operators to predict and adapt to potential dynamic changes, thereby enhancing the cell's operational stability and performance over time [14-17].

This paper summarises the validation results of a novel approach for measuring individual anode currents in real-time monitoring and control of the Hall-Héroult process. Unlike traditional methods that measure currents directly from the anode rod, this method captures readings from the anode beam, enhancing sensor longevity during various operational stages, including anode replacement.

2. Instrumentation and Installation

2.1 Sensor Architecture and Design

We have designed and manufactured an IAM system in-house, some of the details of which were published elsewhere [6]. The system accurately determines the current I flowing along a conductor by measuring the voltage drop V across a known distance L on the conductor with cross-sectional area A. The system also measures the conductor temperature T to compensate for small changes in resistance due to temperature variations. For a conductor with resistivity linear to temperature, its current is calculated with

$$I = \frac{A}{(\rho_1 T + \rho_2)L} V, \quad (1)$$

where ρ_1 and ρ_2 are the resistivity coefficients. Compared to other non-intrusive measurement systems, this method offers a direct and low-cost measurement solution using Ohm's Law.

Based on years of experience developing previous iterations of IAM system, our latest design focuses on superior signal quality and system robustness for scalable commercial deployments. The IAM system measures current from the anode beam instead of the anode rod, allowing uninterrupted measurements through operations such as anode change and beam raising. A dedicated digital sensor measures and processes voltage and temperature data at each beam location at over 100 Hz, enabling distributed processing. As each sensor has its own microprocessor and can function autonomously, they can independently adjust their signal amplifier gain, achieving a high signal-to-noise ratio even for beam locations with naturally small signal magnitude. The sensors, orchestrated by a communication unit, communicate digitally through robust industry-standard Controller Area Network (CAN) protocol to minimise signal degradation and interference associated with analogue transmission used by simpler IAM systems.

environment. These benefits highlight the transformative impact of IAM technology in industrial settings, paving the way for advanced, reliable, and efficient monitoring practices.

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