Measurement of DC Busbar Currents in Aluminium Smelters

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Abstract

Busbar current distribution is an important aluminium electrolysis cell design and operation parameter, which determines the electrical and magnetic equilibrium of the cell. Several methods of measurement of electrical currents in busbars are used in aluminium smelters: voltage probes or forks based on Ohm's law, Rogowski coil clamp-on loops based on electromagnetic induction, magnetic sensors based on Hall Effect and fibre optics current sensors based on Faraday Effect. Some of these devices are fixed on or around the busbars, some are portable. Access to busbars and maximum ambient temperature may be an issue for some devices. The choice of equipment depends on purpose of measurements, accuracy required and cost. In this paper we present and compare the measurement methods and principles, used in aluminium smelters for busbar current measurements, with special emphasis on the latest technology – flexible optical fibre current meter from Smart Digital Optics (SDO). In Emirates Global Aluminium several of these methods are used.

Keywords: Aluminum smelter DC current measurement, millivolt fork, clamp-on current meter, Hall Effect sensors, fibre optics current sensors.

1. Introduction

Electrical current distribution in the busbars and inside the pot is an important parameter of pot design and operation. It determines the magnetic field and current distribution in the liquid aluminium metal pad, which create the electromagnetic forces in the metal pad, responsible for cell magnetohydrodynamic (MHD) characteristics: metal and bath circulation, bath-metal interface deformation and cell instabilities. Current distribution in the busbars between two adjacent pots is determined by busbar design, which is chosen to generate a balanced magnetic field and approximately equal collector bar currents in order to provide MHD equilibrium in the liquid metal of the pot. Current distribution in the cathode collector bars is determined by the busbar and cathode design; it does not change with time, unless the cathode blocks have specific problems, such as cracking or collector bars are attacked by liquid aluminium.

Current distribution in the anode rods mostly depends on the resistance of each individual anode between the anode beam and the liquid metal pad. The largest part of this resistance comes from the thickness of the bath layer below each anode, but also from the bubble coverage of each anode bottom which is a function of local alumina concentration. The resistance on the path through each anode also depends on anode bottom condition (spikes) and on the contact resistance between the anode stubs and anode carbon block. The current of an anode varies over the lifetime of the anode; it is zero or very small for the first few hours after the anode setting and then gradually increases to reach the average value in typically 24 to 48 h. After that it stays more or less constant and is controlled to be within the specified upper and lower limit. The anodes are moved up if the current is above the upper limit and down if the current is below the lower limit; this operation is done with the help of the Pot Tending Machine (PTM) as the pots usually do not have individual anode drives. Therefore, such adjustments have to be limited in number as the PTM and pot operators have limited availability. However, the automatic control of anode currents on experimental pots with individual anode drives has been reported [1], but it was found out that the number of anode adjustments per day has to be limited in spite of the capability to move the anodes up and down automatically. The reason is that the anodes have a self-adjusting capability for current over time, because anode consumption is proportional to the current density on the bottom face of the anode; if an anode carries more or less than average current, the anode consumption will be faster or slower than the average, which adjusts the local ACD and that the currents tend to equalize.

At pot design stage, busbar and collector bar current distributions are determined with mathematical models, which have to be validated with measurements. Any changes of current distribution in cathode collector bars or anode rods due to pot operation can be determined by measurements only. The measurements of current distribution in the busbars can be periodic or continuous. The measurements of collector bar current distribution are most often periodic and are made for mathematical model validation [2] or for detecting specific condition of the cathode blocks, such as collector bar attack by liquid aluminium [3]. The measurement of anode current distribution is most of the time periodic for the control of anode currents [4]. Continuous measurements of anode currents have been made for automatic anode current control [1] or for research to determine how the anode currents change with specific events such as approaching or real anode effects, local alumina concentration, presence of anode spikes, perfluorocarbon (PFC) emissions, etc. [5 - 8]

In this paper we present the principles of measurement of DC currents and discuss applications of each principle to busbar, cathode collector bar or anode rod current measurements.

2. Principles of DC Current Measurement

Four principles of DC current measurement will be discussed:

1) Measurement of voltage drop between two points on the conductor,
2) Rogowski coil,
3) Hall Effect sensors,
4) Fibre optics current sensors, based on Faraday Effect.

2.1. Measurement of Voltage Drop between Two Points on the Conductor

The simplest and most commonly used method is to measure the voltage drop between two points on a conductor at a fixed distance apart. Two voltage probes, either attached to the busbar (Figure 3.2 and 3.4) or fixed on a portable fork (Figure 3.1) or semi-permanent fork (Figure 3.3 left) are used. Voltage drop is measured by a voltmeter or data logger. In modern portable forks, the voltmeter is attached to the holder [4]. Busbar current is determined from Ohm's Law, Equation (2.1):

$$\Delta V = RI \rightarrow I = \frac{\Delta V}{R} = \frac{\Delta V A}{\rho(T) L} \tag{2.1}$$

where:

I	Measured potline current, kA
ΔV	Measured voltage drop between the two voltage probes, mV
R	Electrical resistance of the conductor between the two probes, Ω
A	Conductor cross-section, m^2
L	Distance between the two probes, m
$\rho(T_i)$	Electrical resistivity of the conductor, a function of temperature, μΩm
T	Temperature of the conductor between the two voltage probes.

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