Cell Voltage Noise Removal and Cell Voltage (or Resistance) Slope Calculation

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ABSTRACT

Cell voltage noise removal and cell voltage (or resistance) slope calculation are critical aspects of modern high amperage cell controller operations, yet, those operations are not covered much in the literature. In the present work, the efficiency of several algorithms is compared.

INTRODUCTION

Aluminium reduction cell process control development have been fairly recently summarized by Bearne [1]. Modern high amperage cell control strategies are all based on continuous tracking algorithms [2,3,4,5]. The aim of those continuous tracking algorithms is to operate the cell at the lowest possible concentration of dissolved alumina in the bath because this maximizes current efficiency [1,6]. Those alumina concentration control algorithms are based on alternating between an underfeeding and an overfeeding regime because as explained in [7], using a constant nominal feeding regime is impossible over a long period of time because the negative correlation between dissolved alumina concentration in the bath and current efficiency makes the system unstable.

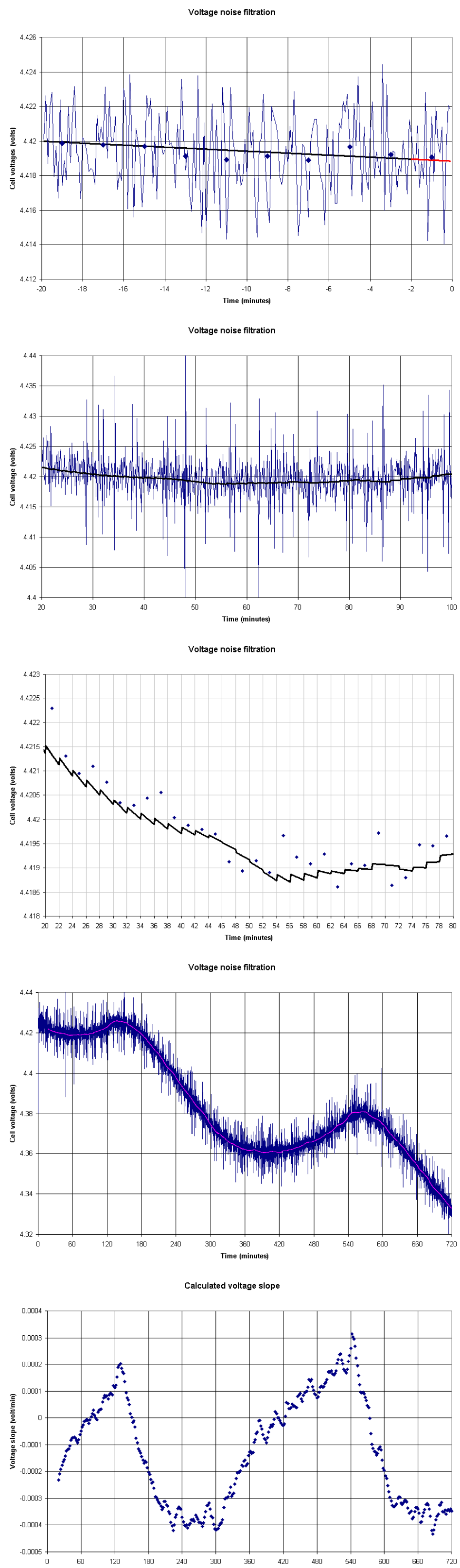
All those continuous tracking control algorithms are using the slope of the cell voltage over time or more accurately the cell pseudo-resistance as an indicator in order to decide when it is time to shift between the underfeeding and the overfeeding regime [1]. However, it is not so easy to accurately evaluate the low frequency slope as the cell voltage (or resistance) also has a high frequency component.

The low frequency component is due to the slow change of the alumina concentration, average anode to cathode distance (ACD), bath temperature etc, while the high frequency component is due to magneto-hydro-dynamic (MHD) generated bath-metal interface long traveling waves and gas driven short bath-metal interface waves. Together those two types of waves are responsible for the high frequency component variation of the cell voltage (resistance) called cell noise. That high frequency noise component must be removed in order to be able to compute the low frequency component driven among other things by the fluctuation of the alumina concentration in the bath, which is the relevant data for the alumina feeding control algorithm.

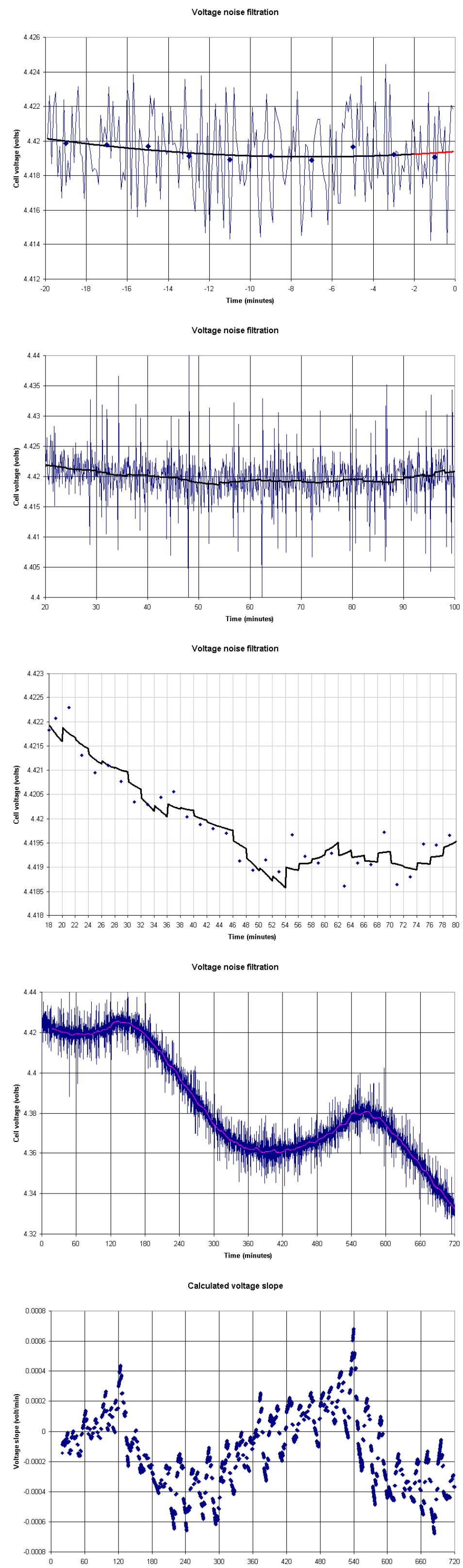
NOISE FILTRATION AND SLOPE CALCULATION

Figure 1 illustrates the first algorithm tested. Raw cell voltage and amperage are measured every 6 seconds. Those raw voltage and amperage are used to compute the cell resistance [1]. In the current work, a cell voltage free of any amperage fluctuation noise is recomputed using the nominal amperage. The cell voltage computed this way every 6 seconds is then averaged every 2 minutes. Finally, the best straight line fitting the last 10 "2 minutes averaged cell voltage" is computed. Every 2 minutes, a new 2 minutes cell voltage averaged value is computed and a new best straight line fitting using the last 10 "2 minutes averaged cell voltage" is computed. Figure 2 presents the results obtained after 40 of such cycles. The smoothed voltage curve presented in Figure 2 was constructed using the red section of the fitted line presented in Figure 1 for each of those 40 cycles. Although it looks like a monotonous curve, Figure 3 presents the same smoothed voltage curve highlighting the fact that there are jumps in the curves. Yet, Figure 4 clearly shows that over a period of 12 hours, this algorithm filtered very well the noise, generating a remarkably smooth low frequency voltage evolution curve. As highlighted in Figure 3, the voltage slope evaluations are discrete, but as highlighted in Figure 5, over a period of 12 hours, those discrete voltage slope evaluations are producing a remarkably continuous curve very well suited to be used as input data for the continuous tracking alumina control algorithm.

Figure 6 illustrates the second algorithm tested. The same amperage fluctuation free cell voltage computed every 6 seconds and averaged every 2 minutes are used, but this time, the best parabolic curve fitting the last 10 "2 minutes averaged cell voltage" is computed. Obviously, as it can be seen comparing Figure 6 to Figure 1, the global fit over the those last 10 averaged points is better but does it means that this more complex and more CPU demanding algorithm computes a more reliable voltage slope for the continuous tracking alumina controller? Figures 7, 8 and 9 present the smoothed voltage curve obtained. When compared with Figures 2, 3 and 4, we can see that taking the extra trouble of computing the best parabolic curve fit instead of the best straight line fit did not resulted in producing a smoother voltage curve, on the contrary! Figure 10 confirms that the voltage slope computed with the second algorithm is a lot noisier. Furthermore, the maximum amplitudes of the slope computed with the second algorithm are less accurate than the ones computed with the first simpler algorithm.



Figures 1 to 5: First algorithm



Figures 6 to 10: Second algorithm

CONCLUSIONS

Numerical algorithms that perform cell voltage noise removal and cell voltage (or resistance) slope calculation have been compared.

High frequency voltage noise can be successfully removed using quite simple averaging and curve fitting techniques.

A more complex and more CPU demanding parabolic curve fitting scheme produced a noisier and less accurate cell voltage slope estimation than a simpler straight line fitting scheme.

Next step would be to test the cell voltage noise removal algorithm "on-line" as part of a continuous tracking alumina feeding control algorithm in a dynamic cell simulator.

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