CELL VOLTAGE NOISE REDUCTION BASED ON WAVELET IN ALUMINUM REDUCTION CELL

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Abstract

For line current fluctuation, cell voltage signals collected in the aluminum electrolysis process have high noise, which has a significant impact on the aluminum reduction cell voltage and precision of the amount of alumina feeding. Based on wavelet de-noising theory this paper analyses and compares different wavelet bases for signal de-noising effect by application of MATLAB modeling simulation and field research. Simulation and processing results of field data show that 5-order Haar Wavelet is a good choice for filtering cell voltage signal, with better prospects.

Introduction

The aluminum electrolysis process has characteristics of nonlinear, time varying and large delay, and strong electric field, magnetic field and thermal field interfere with each other. Thus a number of important parameters in the production process, such as electrolyte temperature and alumina concentration cannot be achieved by online continuous testing [1]. In current times, only the cell voltage signal and the line current are available online, and the resistance calculated by the cell voltage and the current is only online access to reflect the state of the cell signal.

Cell voltage signals collected in the aluminum electrolysis process are with noise, which will affect the identification of the signals and the judgment the status of cell [2]. Many scholars work out a wide variety of de-noising methods according to actual signal characteristics, noise statistical features and their spectrum distribution. The most common method is based on one phenomenon that noise energy is generally concentrated in high frequency, while the true signal spectrum is located in a limited range, so low-pass filter approach can be used to de-noising, such as Fourier Transform, Moving Average Window filter, Wiener linear filters, etc. [3,4].

But the traditional method of matched filter wave can only get better results by more signal prior knowledge. As complexity and randomness of reduction cells work environment, cell voltage signal is inevitable non-stationary. Therefore the wavelet theory gets more attention for its time-frequency characteristics of signal processing and noise reduction [5].

The wavelet transform has multi-frequency characteristics, so it can achieve high signal resolution of local orientation in both time domain and frequency domain, which extract effective temporal, steady-state information and waveform characteristics information in non-stationary signals [6]. In turn, it can reduce noise through distinguishing between different rate signal and noise distribution. In addition, the signal can be removed or reduced correlation by wavelet transform, and it has trend of whitening after noise transformation, so wavelet domain is more favorable for noise reduction than time domain [7]. In this paper, it mainly discusses the application of wavelet transform to analyze noise reductions of cell voltage signals.

Wavelet De-noising Algorithm

The basic method of wavelet de-noising is: Transform signals with noise using multi-scales from time domain to wavelet domain, and extract wavelet coefficients as much as possible in each scale to remove noise in the wavelet coefficients, and then reconstruct signals by using inverse wavelet transform [8].

Selection of Wavelet Base

A very important issue for wavelet analysis in engineering fields is the selection of the optimal wavelet base function. How to select the best wavelet function during wavelet analysis is still questionable [9]. The general principle is on the basis of wavelet base function traits, signal characteristics and other specific requirements.

This paper chooses Haar wavelet as wavelet base function. Haar wavelet has orthogonality and symmetry while the features make it a linear phase, and compact support and highest time resolution of the simplest wavelet base function.

Choice of Filter Order

Mallat (1989) proposed the concept of multi-resolution analysis [10], and calculated the fast wavelet decomposition and reconstruction, which is Mallat Algorithm. Signal x(t) is the orthogonal wavelet decomposition:

$$\begin{cases} x_k^{(j)} = \sum h_{0(n-2k)} x_n^{(j-1)} \\ d_k^{(j)} = \sum g_{0(n-2k)} x_n^{(j-1)} \end{cases} \quad (1)$$

$x_k^{(j)}$—scale coefficient,
$d_k^{(j)}$—wavelet coefficient,
h_{0k}、g_{0k}—multi-resolution analysis filter coefficients,
j—decomposition order.

Decomposition of wavelet reconstruction process is the inverse operation, and the corresponding reconstruction formula is

$$x_n^{(j)} = \sum_k h_{1(n-2k)} x_k^{(j+1)} + \sum_k g_{1(n-2k)} d_k^{(j+1)} \quad (2)$$

Here the synthesis filter coefficients (h_{1k}, g_{1k}) are determined by analysis filter coefficients.

Signals can be decomposed at different scales by multi-resolution analysis of wavelet, and the signal intertwined with composition of mixed-signals of different frequency was made into different sub-band signals [11]. The essence of wavelet filtering is to let signals pass through combination of high and low filter, so the signal is decomposed into high and low frequency band, and continue this process until the need is met. As long as we select appropriate decomposition order, we can get the required width and starting and ending frequencies of the frequency band. The concrete steps by using wavelet decomposition and de-noising reconstruction are: decompose a noisy signal into different frequency band scales, set noise frequency band zero, and then reconstruct the wavelet, so as to achieve the purpose of de-noising.

Useful information on cell voltage signal spectrum is concentrated in one section of frequencies, and decomposition of appropriate layers using wavelet theory can decompose the signal to a specific scale, which is conducive to the separation of signal and noise, so as to extract signal characteristics to analyze.

Results and Analysis

This paper is based on noise signal extracted by cell voltage data in a cell production process, which is added voltage step signal, finally establishing cell voltage signal with noise, and analysis of the cell voltage signal with noise. Extracted noise signal is shown in Figure 1, and noisy step voltage signal is shown in Figure 2.

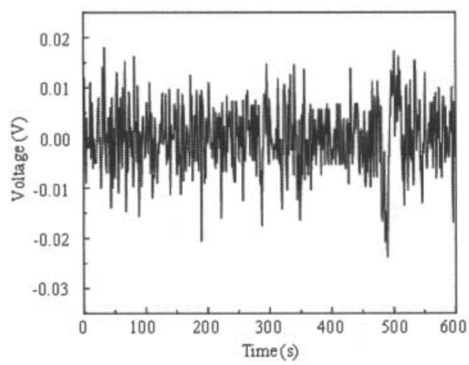


Figure 1. Extracted noise signal.

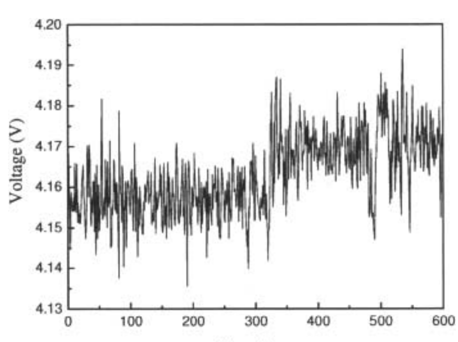
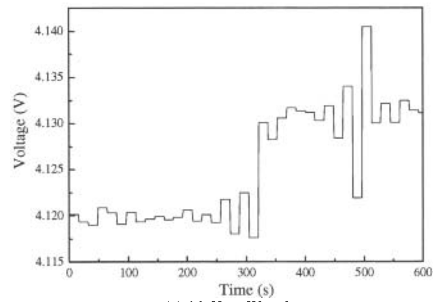
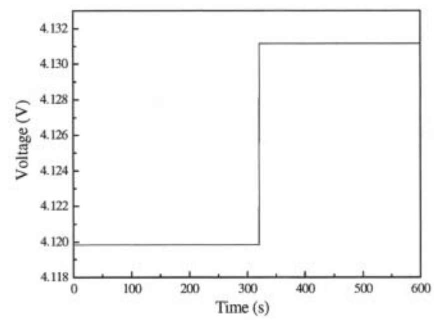


Figure 2. Noisy step voltage signal.

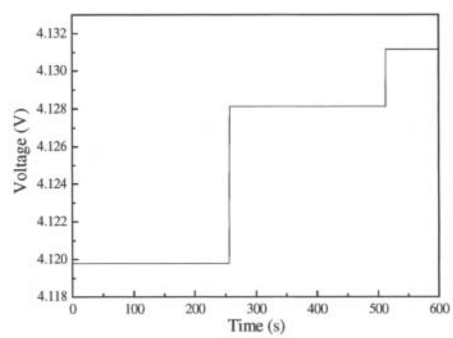
Select different order of the Haar wavelet to filter voltage signal, analyze filtering effect of Haar wavelet in different order levels. Filtering effect of different order levels Haar wavelet is shown in Figure 3.



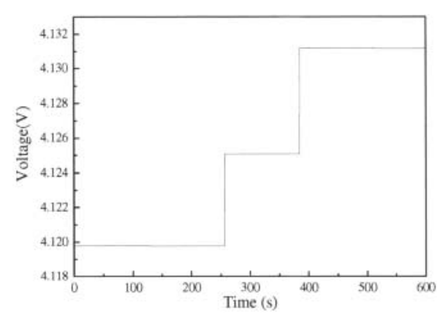
(a) 4th Haar Wavelet



(b) 5th Haar Wavelet



(d)7th Haar Wavelet



(c)6th Haar Wavelet

Figure 3. Filtering effect of different order levels Haar wavelet.

From the above diagram of the Haar wavelet filter effects we can see that noise is still confused in the voltage signal by using 4-

order Haar wavelet filter, and it has not been filtered, so the filter effect is not obvious; By using 6,7-order Haar wavelet filtering, the filtering effect is obvious, but some low-frequency voltage signal is filtered out. In multiple wavelet filter, 5-order Haar wavelet filter is the best.

By 5-order Haar wavelet de-noising, wavelet decomposition and reconstruction of signal characteristics are shown in Figure 4. Coefficients of the 5-order low-frequency layer after wavelet decomposition are considered as cell voltage changes, while other factors can be treated as a cell noise, therefore we reconstruct low frequency coefficients of order 5 to get the de-noised cell voltage.

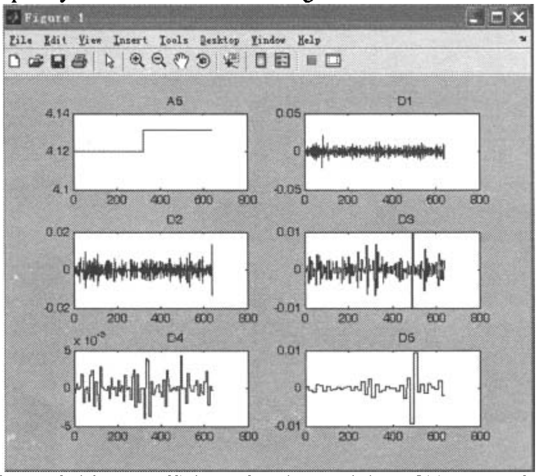


Figure 6. Floor coefficient after the resolving of Haar wavelet.

5-order Haar wavelet filter works well out of the basic reduction step by waveform after de-noising back cell voltage, and the step signal error is below 4.92×10^{-4} V.

Conclusion

Wavelet de-noising transform can achieve precise reduction of the voltage step signals, and 5-order Haar wavelet has better noise reduction effect, with higher recognition accuracy. Wavelet noise reduction technology can reduce the monitored cell voltage with characteristic parameters to a number of data, which is conducive to the realization in computer. The program by the computer implements all calculations with high accuracy of correct diagnosis for reduction cell work state, and is conducive to online monitoring and real-time identification. Furthermore we can reduce the error of alumina concentration identification using resistance calculated by the cell voltage and the current.

Acknowledgements

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