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Fuzzy adaptive signal filtering system for arc steel-melting furnace control system

Abstract *A mathematical model of signal filtering for arc steel-melting furnace regimes control system based on fuzzy output system is proposed. Variable model parameters and approaches to the rules base of fuzzy production system are substantiated.*

Keywords: filtering, averaging, fuzzy logic, noise, adaptation.

Introduction

Steel melting process in electric arc furnaces (EAF) is accompanied by continuous action of non-stationary random parametric and coordinate perturbations in the melting area and power supply circuit of three-phase system of arcs. The process of the EAF electric mode (EM) coordinates change has dynamic, unsteady and non-symmetrical nature. Given the presence of high-power electromagnetic fields generated by power appliances (furnace transformer power is 1 - 150 MVA) of EAF, the primary EM coordinates sensor signals and control system signals are noisy.

A characteristic feature of these signals is the fact that amplitude and frequency parameters of noise and disturbances signals spectrum vary during the melting in a wide range. These factors lead to significant noise in the electrodes movement control signals, reducing the quality indices of arc length and voltage, current and power control dynamics.

Problem formulation

Therefore, to improve the quality of EM coordinates regulation, signal filtering is an important task. Mathematical model of the filtering process should be adaptive and take into account the continuous change of the useful signal and noise amplitude and frequency parameters ratio. One of the viable approaches to successful solution of this problem is usage of mathematical foundations of fuzzy sets. This is due to the lack of precise mathematical description of parameters changes of useful signals and noise stochastic characteristics.

Research results

Incoming analogy signals of the primary sensors in digital systems are sampled, i.e. are presented by lattice functions $y(t=i\tau)$, $i=\overline{1,N}$. Basing on these signals and using some control law (for instance differential) electrodes movement control signals $U_K(t=i\tau)$ are formed. Control signals noise filtering becomes a particularly important task when the differential component in the model of control signal forming is used. Such a component significantly increases the noise, because it exists in the higher frequency range comparing to the useful signal frequency.

Mathematical model of noisy analogy signal $y(t)$ is represented by the following expression:

$$y(t)=y_K(t)+\xi(t)=A^{\mathrm{T}}\cdot\Psi(t)+\xi(t)=\Psi^{T}(t)\cdot A+\xi(t), \quad (1)$$

where $A^{\mathrm{T}}=(a_0,a_1,...,a_{n-1})_{(1\times n)}$ – is vector of unknown parameters of signal $y(t)$ mathematical model;

$\Psi^{\mathrm{T}}(t)=(\psi_0(t),\psi_1(t),...,\psi_{n-1}(t))_{(1\times n)}$ – is a vector of given basic functions; $\xi(t)$ – is random process (noise); $y_K(t)$ is useful signal (without noise).

As a result of the signal $y(t)$ analogy to digital conversion procedure, its digital representation in the form of lattice function is obtained:

$$u(t=\tau)=A^{T}\cdot F(t=\tau)+\xi(t=\tau)=u_1;$$

$$u(t=2\tau)=A^{T}\cdot F(t=2\tau)+\xi(t=2\tau)=u_2; \quad (2)$$

....;

$$u(t=N\tau)=A^{T}\cdot F(t=N\tau)+\xi(t=N\tau)=u_N.$$

Sampling frequency $f=1/\tau$ is chosen twice higher than the maximum frequency of the signal $y(t)$ spectrum on the full duration of melting.

The essence of the filtering procedure is to find such a continuous function $\bar{y}(t)$, for which we get the best lattice function approximation by least mean squares criterion(1). Mathematically, this filtering criterion can be written as:

$$\min_{A}(\xi^{T}\cdot\xi)=\min(Y-X\cdot A)^{T}(\mathrm{Y}-\mathrm{X}\cdot), \quad (3)$$

where $X=\begin{pmatrix} f_0(\tau) & f_1(\tau) & \dots & f_{n-1}(\tau) \\ \vdots & \vdots & \ddots & \vdots \\ f_0(N\tau) & f_1(N\tau) & \dots & f_{n-1}(N\tau)\end{pmatrix}_{(N\times n)}$ – is a matrix, formed of basic functions.

Taking into account continuous signal $y(t)$ spectrum change during melting, both by amplitude and frequency parameters, there is a need to adapt the parameters of the filtering process mathematical model to the above spectrum changes.

Variable parameters of the model (3) are vector elements A of digital filtering expression (1) parameters, the order of approximating polynomial and the width of the window, which is the number N of samples $\{y_1,y_2,y_3,...,y_{N1}\}$.

Filtering estimation $R=\gamma+\delta a_0$, that corresponds to the above-mentioned filtration model, has the extremum (minimum), which corresponds to the optimal number of samples N. It is reasonable to obtain the best filtering $R(N^{*})\Rightarrow\min$ on the basis of fuzzy sets.

Input linguistic variables of fuzzy logic output system are the mean square error of an approach γ and its magnitude δa_0, and output - the optimum count of values $y(t_i)$ on filter "window" of width $N^{*}\tau$. For a fixed sample value τ by time fuzzy output system will help to get the smallest error R of noisy signals filtering using the obtained fuzzy model.

REFERENCES

[1] Красовский А.А Оптимальные алгоритмы в задачах идентификации с адаптивной моделью // Автоматика и телемеханика.-1976.- №12.-С.75-82.

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