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Increasing Measurement Accuracy via Corrective Filtering in Digital Signal Processing

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Abstract: This paper considers the problem of eliminating the errors that arise in the phase of processing, taking into account the increased demand for digital signal processing of the measurement results in the oil and gas industry. Investigated the issues around corrective filtering and discrete averaging in digital signal processing.

Keywords: Non-sinusoidal signal, Spectrum of signal, Mathematical expressions, Noise and interference, Digital measurement, Average value.

I. INTRODUCTION

Any measured value, for example, the mains voltage is a sine wave signal. As a part of this signal has only one harmonic. As a result, the analog measurement value we get a non-sinusoidal signal. It is a sinusoid having a composition further odd harmonics. The causes of these harmonics are noise and interference imposed on the main signal. Therefore, the measured signals, in most cases (80%) are non-sinusoidal [1,2].

Curves Instant continuous signal values are most useful, but not always foreseeable. Therefore, for control and analysis of controlled processes and facilities is of great importance in the determination of real-time integral signal parameters (ISP). Recent characterize the total amount of matter and energy to be made and received in the production for a certain period of time, regime performance and features, is the average of the measured values, etc. Specificity determination ISP digital methods and tools are to perform discrete averaging (DA) or discrete integration (DI) values, continually changing over time.

Among digital techniques ISP measurements are widely used so-called method of digital processing of the results of direct measurements of instantaneous values of the signal during averaging (integration). In recent years, interest in this method has increased significantly, due to the possibility of the introduction of computing power in the measurement channels in dealing with this kind of measurement tasks. This problem becomes even more complicated when IRS digital measurements of electrical signals of complex shape (non-sinusoidal signals). Nevertheless, the well-known advantages of electrical control and measurement methods of physical quantities contribute to more widespread primary data converters with the outputs in the form of fixed and variable currents and voltages. AC signals are more informative, and in some cases are the only possible form of obtaining measurement data, particularly in the objects of production and conversion of electrical energy.

In the Table 1 shows the mathematical expressions to define commonly used in practice, measurements of their own and mutual ISP [3-10].

In the transition from the continuous integration of the numerical algorithms using the Table 1, it is necessary to draw attention to the fact that almost all the algorithms used by the remote operator.

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Table 1. Characteristic own IPS.

Non-random signals	
IRS	**The formula for determining the IRS**
The current average value	$x_T = 1/T \int_t^{t+T} x(t)dt$
Average value	$x_{cp} = 1/T \int_0^{T} x(t)dt$
Average rectified value	$x_{CB} = 1/T \int_t^{t+T} \lvert x(t) \rvert dt$
Mean square value	$x_{ck} = \left[1/T \int_t^{t+T} x^2(t)dt \right]^{0,5}$
Fourier coefficient	$C_{nx} = 1/T \int_0^{T} x(t)e^{-j\omega nt}dt$
Shape factor	$K_{\phi} = x_{ck} / x_{CB}$
Random signals	
Median value (first-order moment)	$M_1[x(t)] = \lim_{T\to\infty} 1/T \int_0^{T} x(t)dt$
The mean square value (second-order moment)	$M_2[x(t)] = \lim_{T\to\infty} 1/T \int_0^{T} x^2(t)dt$
Average square value	$x_{ck} = \{M_2[x(t)]\}^{0,5}$, $\sigma_x = \{D[x(t)]\}^{0,5}$
Dispersion	$D[x(t)] = \lim_{T\to\infty} 1/T \int_0^{T} \{x(t) - M_1[x(t)]\}^2 dt$
Spectral function	$S_x(\Omega) = \int_{-\infty}^{\infty} x(t)e^{-j\Omega t}dt$
Autocorrelation function	$R_x(\tau) = \lim_{T\to\infty} 1/T \int_0^{T} x(t)x(t+\tau)dt$
Power spectrum density	$G_x(\Omega) = \int_{-\infty}^{\infty} R_x(\tau)e^{-j\Omega\tau}d\tau$

To perform the control class of continuous functions $\tilde{C}^{(m)}[0,T]$ uses quadrature formula of the form:

$$\bar{I} = \frac{1}{M}\sum_{i=0}^{M-1} y(iT_0) , \qquad (1)$$

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Where,

$T_0 = \frac{T}{M}$ – time sampling step.

Consider the case where a non-sinusoidal signal interacts with a random signal centered; in particular, find out how the spectrum of the product of these signals [11-15]. As a non-sinusoidal signal source accepts a sine wave superimposed on it 13 odd harmonics of the form:

$$y(ik) = \sum_{n=1}^{2N+1} sin(\omega knT_0), \quad N = \overline{1,6}$$

Where ω - the carrier frequency of the signal, T_0 - sampling frequency (T_0 = 1/1300), к - discrete sample numbers, n - harmonic number.

As a random signal centered considered uniformly distributed on the interval [0, 1] signal generated by the built-in Matlab rand. The spectrum of the original signal is calculated in Matlab software environment using a fast Fourier transform-function fft. Fig.1 (a, b) shows the original signals in Fig.1 (v, q) - spectrum of the original signals.

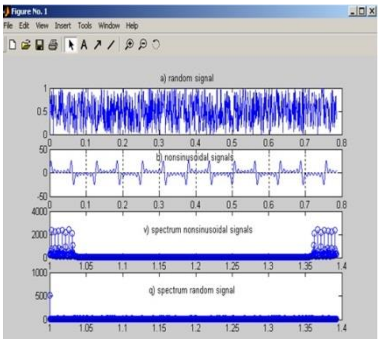

Fig. 1. Spectrum of input signal a) random signal (interference); b) a non-sinusoidal signal; v) non-sinusoidal signal spectrum; q) spectrum of a random signal.

Further, the resulting product signal is non-sinusoidal and random signals received resulting signal whose spectrum is shown in Fig. 2a. As seen in Fig. 2a, the resultant spectrum contains in its structure a certain number of harmonics (13).

To suppress these harmonics we used a method of discrete averaging the resulting signal at regular intervals. The calculations shown in Fig. 2b show that in the spectrum significantly reduced the impact of additional harmonics. Their amplitude was the order of 2, that is, the suppression of the spectrum was almost 1,000 times. And it shows the possibilities of correcting discrete averaging operator with respect to the non-sinusoidal signals.

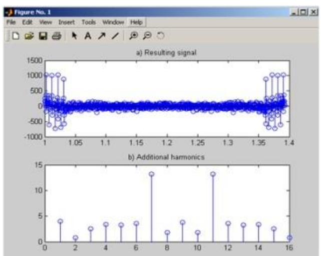

Fig. 2. Spectrum significantly reduced the impact of additional harmonics a) a non-sinusoidal signal spectrum; b) the discrete signal spectrum after averaging.

A similar calculation was made by us in relation to the non-sinusoidal signal of the form (1) and systematic error of about 2 described function of the form:

$$\overline{\varepsilon}(t_k) = \sum_{j=0}^{2} a_j t_k^j , \qquad (2)$$

where t_k - discrete samples bias a_j - polynomial coefficients describing this slowly changing error.
Figs. 3 (a, b) and 3 (c, d) shows the original signals and their spectra - range of bias and non-sinusoidal signal. Fig. 4a shows the spectrum of the resulting signal is equal to the product of a non-sinusoidal signal, and systematic errors. The result of the control in relation to the resulting signal is shown in Fig. 4b.

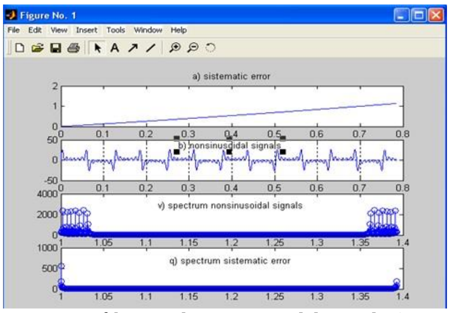

Fig. 3. Initial spectrum of signals and their spectra-range of bias and non-sinusoidal signal. a) systematic error; b) a non-sinusoidal signal; v) non-sinusoidal signal spectrum; q) range of systematic errors.

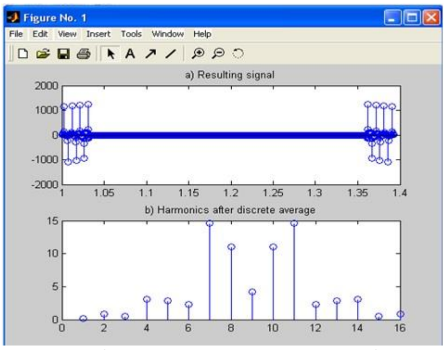

Fig. 4. a) the spectrum of the input signal; b) spectrum after digital averaging.

As can be seen from this figure, the spectrum as a result signal of the discrete averaging significantly decreased. Comparative analysis of the results of the experiment with the random and systematic errors shows that it is better suppressed bias. Consequently, discrete averaging operator, applied to both types of error is a correction with respect to all types of errors. Thus, one can say that the digital averaging operator applied to both types of error correction is to all kinds of errors. This has been proven with simulations in Matlab program.

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