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Improvement of Metrological Characteristics of Inductive Displacement Sensor of Movement Based on Digital Vector Diagram Reconstruction of Signals In Windings

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Abstract

Suggested the method of differential inductive displacement sensor digital signal processing based on the vector diagram reconstruction in the measuring circuit composed of a driving signal windings and the received signal. The proposed method showed high noise immunity due to detuning from network interference and accuracy of differential displacement inductive sensors, as well as possible to reduce the operating frequency, thereby reducing the influence of capacitive coupling to the influence of the cable line. Thus, the use of digital signal processing has improved the performance of meteorological sensors and without significant changes in their mechanical and analog parts, due to the use of high-performance digital signal processing methods.

Keywords: Wavelet function, digital signal processing, linear displacement transducer.

Introduction

Differential inductive displacement sensors are widely used in engineering systems for various purposes. They can be used not only to determine the displacement and to measure the pressure force level flow of gas and liquid, etc... In this case, the measured parameter by various sensing elements is converted into a movement, which is determined by an inductive transducer.

Taking into account the development of methods and tools for digital signal processing it is important to pay attention to the enhancement of the metrological characteristics of inductive displacement sensors by applying not due to extensive improvements precision machining parameters or analog electrical components, and error-correcting due to modern methods of digital signal processing.

Problem Definition

Differential inductive displacement sensors have proven themselves when working in difficult conditions such as high temperatures, radiation levels, etc., wherein the sensor is separated from transducer with the long cable line. Under these conditions, the measurement results are beginning to have a major impact of breakthrough, interference and capacitive coupling between the signal wires. These factors contribute to uncontrolled changes on the incoming signal to the electronic unit, as a result of which the required information can not be accurately determined. Therefore, on the design schedule of the control instrumentation have tacked special measures to prevent induced interference and interference of conductors, which complicates the design of sensors and, nevertheless, did not conclusively get rid of the interference.

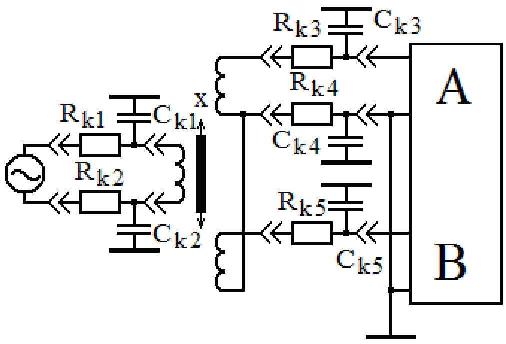

Figure 1: Scheme of differential inductive displacement sensor with cable line

On Figure 1 is given the scheme of differential inductive displacement sensor with cable line, which parameters is concerned with resistors $R_{k1} \div R_{k5}$, and capacitors $C_{k1} \div C_{k5}$. Network interference exert significant influence on long cable line.

Standard measures to struggle this kind of interference is the detuning of the frequency of the network and its multiple harmonic components. Thus, for example, often uses the frequency 1875 Hz, which lies between 37 and 38, the harmonic component of the network signal.

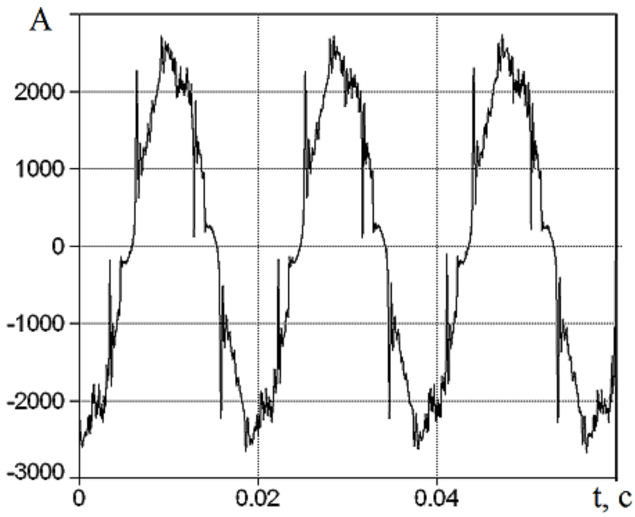

Figure 2: Example of power supply signal 50 Hz

This frequency is sufficiently easily filtered by analog filter network interference, but an increasing the frequency leads to an increase in the capacitive coupling between the conductors of the cable line and leads to increased interference signals that, in turn, reduces the accuracy of the sensor.

The Proposed Method For Solving The Problem

When processing signals from differential inductive sensors decisive influence can have selection of type of determining parameters of signal:

– Differential methods involving measurement of the signal at a certain time;
– Integral methods, which evaluate the characteristics of the signal over a time interval.

Using differential techniques often leads to a simpler implementation of the measuring device, since the measurement is subjected to a single parameter, directly or indirectly, related to the estimated value. However, in industrial practice, complex interference effects casts doubt on the adequacy of the instantaneous values of the signal in a randomly chosen time.

In contrast, the parameter of estimation within a certain time interval allow reducing the influence of noise using spectral methods, statistical and regression analysis, digital filtering, etc. These methods combine the use of varieties of the convolution of functions, one of which is a signal, which measured over a time interval, and the second - an analytical function. Known properties of integral transforms is increased resistance to impulse noise characteristic of modern industrial systems.

One of the integral methods is the direct reduction of the vector diagram [1]. Figure 3 is a flow diagram of a harmonic vector process.

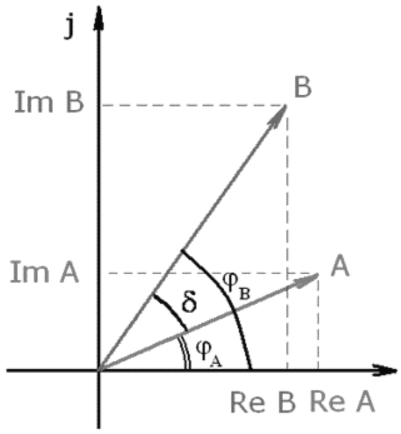

Figure 3: Example of power supply signal 50 Hz

The δ between angels φ_A and φ_B can be found from expression (1) [1]:

$$\delta = arctg\left(\frac{\operatorname{Re} A \cdot \operatorname{Im} B - \operatorname{Re} B \cdot \operatorname{Im} A}{\operatorname{Re} A \cdot \operatorname{Re} B + \operatorname{Im} A \cdot \operatorname{Im} B}\right) \quad (1)$$

Signal amplitudes can be found on expression (2)

$$A = \sqrt{\operatorname{Re} A^2 + \operatorname{Im} A^2} \quad B = \sqrt{\operatorname{Re} B^2 + \operatorname{Im} B^2} \quad (2)$$

Vectors $\vec{A}$ and $\vec{B}$ on the figure 3 can describe various proceeding processes in measuring equipment. In our case, vectors $\vec{A}$ and $\vec{B}$ really describe batching of processes in different data processing channels, at the same time expression (1) describes shift of phases between output signals, and expression (2) describes amplitudes of these signals. Required moving proportionally to attitude of difference and the amount of amplitudes (3):

$$x = x_0 + b \cdot \frac{A - B}{A + B} \quad (3)$$

where b - specifies the steepness, x_0 - displacement of zero, x is the desired movement.

Achievement of Described Approach

To implement the method of direct reduction of the vector diagram is proposed to use orthogonal transformation, which does not change the amplitude ratios in the desired frequency range [2, 5-7], at the same time removes from the spectrum the constant component of the signal. Required properties of the wavelet transform Morley function [3, 4], which is described by the expression (4):

$$\psi(t) = (\cos 2\pi ft + j \cdot \sin 2\pi ft) \cdot e^{-\frac{(2\pi f\tau)^2}{k}} \quad (4)$$

where $\psi(t)$ – wavelet function, k – the damping coefficient of the wavelet function Morley, dependent from integration boundaries [3], f – frequency, $j=\sqrt{-1}$ – imaginary unit.

Wavelet-transformation consists in calculation of the type integral (5)

$$W(f)=\frac{1}{a}\int_{-\tau_{гр}}^{\tau_{гр}}\psi(\tau-t)X(\tau)d\tau \qquad (5)$$

where $X(t)$ – observable signal, t – moment time of analyze, a – scale factor of wavelet function , $\pm\tau_{гр}$ – limits of integration, defined by the expression (6):

$$\pm\tau_{гр}=\pm x\cdot T=\pm x\cdot\frac{1}{f} \qquad (6)$$

where f and T – frequency and period of analyzed signal properly, x –quantity of half-cycles of analyzed signal.

The function can be chosen in such a way that is attenuated between the main (50Hz) and second (100 Hz) harmonic components of the mains voltage. At the figure 4 a) shows the spectrum of the mains voltage, as shown in figure 4 b) the frequency response on the proposed Wavelet function Morley c $x=\pm 33{,}5$

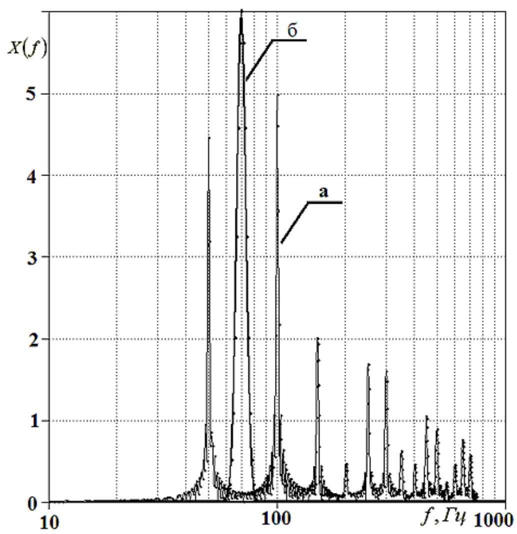

Figure 4: Range of supply voltage (a), the frequency response of the proposed wavelet function Morley c $x=\pm 33{,}5$ (б)

Electrical block of device for measuring distance is made on programmable logic IC, hardware implements convolution with a pre-prepared coefficients of wavelet function for two measuring channels. Also in programmable logic, IC was realized signal generator of excitation. The measured value can be transmitted via RS-232. As a result of research influence of the length of cable on the precision of displacement were obtained the following results:

At the excitation frequency 2000 Hz:

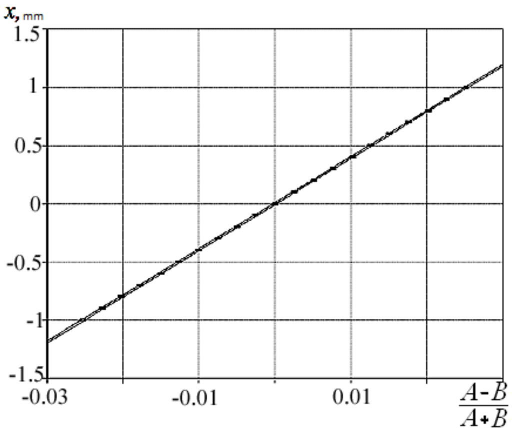

Figure 5: Measured results at the excitation frequency 2000 Hz

With cable: $x = 0.0697 + 39.6091 \dfrac{A-B}{A+B}$

Without cable: $x = -0.0097 + 39.6782 \dfrac{A-B}{A+B}$

From these formulas, we see that there is a significant change in the zero offset and slope, which shows the influence of the cable line. At the excitation frequency 225 Hz:

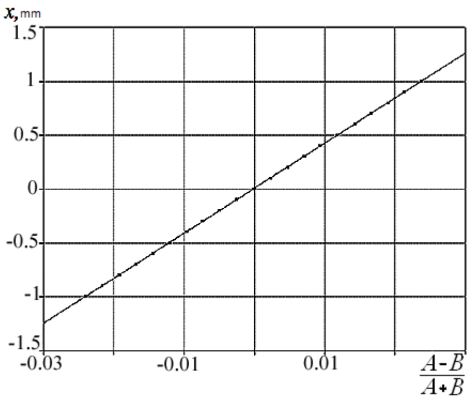

Figure 6: Measured results at the excitation frequency 225 Гц.

With cable: $x = 0.0058 + 16.7354 \dfrac{A-B}{A+B}$

Without cable: $x = 0.0041 + 16.7414 \dfrac{A-B}{A+B}$

Results of formulas show significantly less influence of the cable line.

Conclusion

The proposed method showed high noise immunity due to detuning from network interference and accuracy of differential displacement inductive sensors, as well as possible to reduce the operating frequency, thereby reducing the influence of capacitive coupling to the influence of the cable line. Thus, the use of digital signal processing has improved the performance of meteorological sensors and without significant changes in their mechanical and analog parts, due to the use of high-performance digital signal processing methods.

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