

*rail circuit, device,
code current parameters control*

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TO THE QUESTION ABOUT CHECKING PARAMETERS OF CODE CURRENT OF RAIL CIRCUIT

This paper deals with the question of definition of code current parameters and spectrum interference in rail net. It is proposed the hardware-software complex for this purpose. It is realised on the base of personal computer and microprocessor techniques.

ROZWAŻANIA NA TEMAT PARAMETRÓW KONTROLNYCH PRĄDU KODOWANEGO W OBWODACH TOROWYCH

Artykuł omawia kwestię definicji parametrów prądu kodowanego i zakłóceń widma w rzeczywistej sieci kolejowej. Dla tego celu proponuje się „zestaw sprzęt – oprogramowanie”, który jest realizowany z wykorzystaniem komputera osobistego i technik mikroprocesorowych.

1. INTRODUCTION

According to the Manual for maintenance of devices of the signal system, centralization and block systems it is necessary to check its work periodically with the help of system "Control", placed in a cars – laboratories, that allowed to measure parameters of automatical locomotive signalization code current [1]. This system is intended for measurement of a code current by frequency 25, 50 and 75 Hz, definition of its time and amplitude parameters, calculation of coordinate of a rail circuit (RC), control isolate connection of rails and speed of movement of the rolling-stock.

Measurement of code current should be reliability and whenever possible exclude of labour-consuming, long on time and deals with walk to the field operation. That it is impossible to carry out at a manual control parameters of current. Besides the realization of measurements on railway section deal with the necessity of sever observance of the safety precautions regulations.

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The check with the help of car - laboratory allows us to determine first of all deviations in adjustment of RC and code equipment, but don't gives possibility to measure phase of code currents of station RC, value of return tractive current in rails and spectrum of interferences, asymmetry code and tractive currents. As for the numerical parameters of code signals it is defined with the error $\pm 10\%$.

So it is necessary to create measuring system for the check of parameters of code signals in rail circuit with more accuracy and allowing to expand number of checking parameters and to create electronic bases of the measured and designed data. It will promote more complete and authentic analysis of serviceability of rail circuits.

2. THE MATHEMATICAL DESCRIPTION TRANSFER PROCESSES OF THE INFORMATION INTO LOCOMOTIVE'S COILS

In the system automatic locomotive signalling system (ALS) there is a continuous communication between track and locomotive devices. The ALS inductors C1 and C2 are situated before the first wheel pair of locomotive. Coils C1 and C2 connects inductively, by means of a magnetic field, series and towards each other. Magnetic field is formed around of rails R1 and R2 by an alternating code current. Thus, within the limits of each rail circuit (RC) there is a separate channel of communication. The circuit of transfer of the information for one RC is shown in a Fig.1.

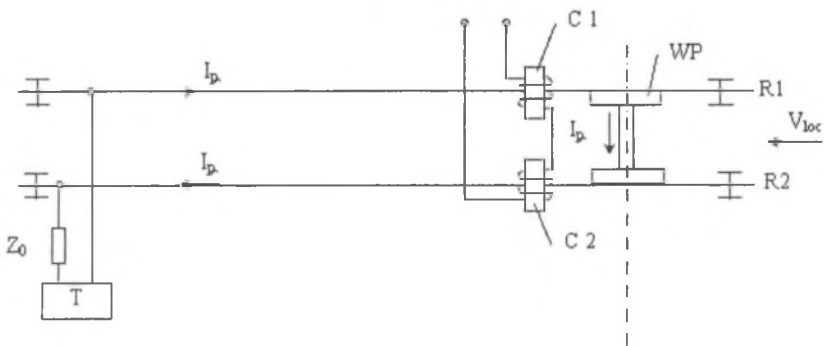


Fig.1. The circuit of transfer of the information on a rail circuit to the locomotive's receptors

On the output of a rail circuit the transmitter T of code signals is placed. Rail circuit shunts by first wheel pair WP of locomotive in the end. The current I_p in the channel of communication formed by rails R1 and R2 and wheel pair WP flows under each of coils opposite. Then, total induced electromotive force is equal

$$\vec{E} = \vec{E}_1 + \vec{E}_2 \quad (1)$$

where – electromotive force, induced in coils C1 and C2 accordingly.

Let's consider the problem on radiation of electromagnetic energy by an element of a current. Let's replace a rail by an equivalent round conductor of infinite length. The code current of the sine wave form follows in it. Let positive direction of a current in a rail coincides with a direction of an axis z.

For definition of a magnetic induction and magnetic flow running through coils of ALS, we shall take advantage of vector potential of a magnetic field \vec{A} . The direction of this vector coincides with a direction of current in conductor. Vector - potential has the following connection with a magnetic induction and magnetic flow.

$$\vec{B} = \text{rot } \vec{A} \quad (2)$$

$$\Phi = \int_S \vec{B} d\vec{S} = \int_S \text{rot } \vec{A} d\vec{S} = \oint \vec{A} d\vec{l} \quad (3)$$

where - \vec{B} vector of a magnetic induction, T;

S - area of a surface, crossed by a magnetic flow, m²;

Φ - magnetic flow, T m².

The size and direction of vector potential of a magnetic field depend on current i , flowing in conductors of length dl and on the Poisson equation is equal

$$\vec{A} = \frac{\mu \cdot \mu_0 \cdot i \cdot d\vec{l}}{4 \cdot \pi \cdot R} \quad (4)$$

where - μ magnetic permeability of environment (steel of the core), H/m;

μ_0 - magnetic constant, H/m;

R - distance from a radiating conductor up to a point in space, m.

In alternative magnetic field in view of effect of delay of a wave, which is shown at transfer of a signal on high frequencies (for example, in case with tonal rail circuits or high frequency interferences) shall write down vector - potential as

$$\vec{A} = \frac{\mu \cdot \mu_0 \cdot I_m \cdot e^{j\omega(t - \frac{R}{v})} \cdot d\vec{l}}{4 \cdot \pi \cdot R} \quad (5)$$

where v – speed of spreading wave, m/s.

For definition of a vector of a magnetic induction we took advantage of cylindrical system of coordinates. Let's write this dependence in the complex form. Generally it looks like

$$\vec{B} = \text{rot } \vec{A} = r^{-0} \cdot \left(\frac{\partial \dot{A}_z}{r \partial \alpha} - \frac{\partial \dot{A}_\alpha}{\partial z} \right) + \alpha^{-0} \cdot \left(\frac{\partial \dot{A}_r}{\partial z} - \frac{\partial \dot{A}_z}{\partial r} \right) + z^{-0} \cdot \left(\frac{\partial (r \dot{A}_\alpha)}{\partial r} - \frac{\partial \dot{A}_z}{r \partial \alpha} \right) \quad (6)$$

As vector - potential has only component \dot{A}_z and $\frac{\partial R}{\partial r} = \frac{r}{R} = \sin \theta$, that

$$\dot{B} = -\alpha \cdot \frac{\partial \dot{A}_z}{\partial r} = -\frac{\partial \dot{A}_z}{\partial R} \cdot \frac{\partial R}{\partial r} = \frac{\mu \cdot \mu_0 \cdot I_m d l \cdot \sin \theta}{4 \cdot \pi} \cdot \left[\frac{1}{R^2} \cdot e^{-jw(t-\frac{R}{v})} + \frac{j \cdot w}{R \cdot v} \cdot e^{-jw(t-\frac{R}{v})} \right] \quad (7)$$

where r - projection of a piece R on a plane z .

For an indefinitely long conductor (rail line), induction of a magnetic field in a point on distance R from radiator (and $r = R$),

$$B(t) = \frac{\mu \cdot \mu_0 \cdot I_m}{2 \cdot \pi} \cdot \left[\frac{\sin(w \cdot t - \frac{w \cdot R}{v})}{R} + \frac{w}{v} \cos(w \cdot t - \frac{w \cdot R}{v}) \right] \quad (8)$$

According to the law of an electromagnetic induction electromotive force induced in the ALS coils is equal

$$E(t) = -\frac{W_B \cdot d\Phi}{dt} = -\frac{\mu \cdot \mu_0 \cdot I_m \cdot \pi \cdot d^2}{2 \cdot \pi \cdot 4} \cdot \left[\cos(w \cdot t - \frac{w \cdot R}{v}) \cdot \frac{w}{R} - \sin(w \cdot t - \frac{w \cdot R}{v}) \cdot \frac{w^2}{v} \right] \quad (9)$$

where W_B - number of winds of the coil.

The results of modelling of virtual value of electromotive force on the distance R from the source of radiation (rails) for existing rail circuits in Ukraine by low frequencies (25, 50 and 75 Hz) are given below (Fig.2). Current in the rail is equal 10 A. The calculation was executed without taking into account of the phenomenon of wave delay, because it has no for low frequencies. That is why equation (10) is simpler. The relative error between the measured and calculated data is $\pm 3.5\%$.

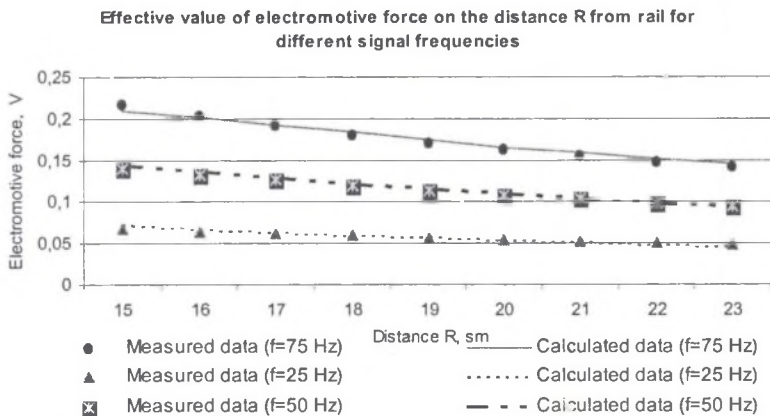


Fig.2. Electromotive force on the distance R from rail at the code current by value of 10 A

So we have equation of electromotive force induced in the coils of ALS, which is allowed to take into account effect of delay of a wave in case with tonal rail circuits or high frequency interferences. The dependence between code current and electromotive force in inductors is received. This will be used at the definition of parameters of code current with the help of the device, at which the detector of the information are locomotive coils.

3. THE HARDWARE OF A MEASURING COMPLEX

For definition of numerical and time parameters of signal current the hardware-software measuring complex is offered, which block diagram is given in a Fig.3.

This is realized as a additional device to the personal computer (PC) such as IBM PC. It carries out digital processing of analog signal from the locomotive coils and contains the following basic units: the block of commutator, dividers, limiting amplifiers, analog-digital converter (ADC), multiplexers, generator of tact impulse, program timer, control device (registers of the data and operate).

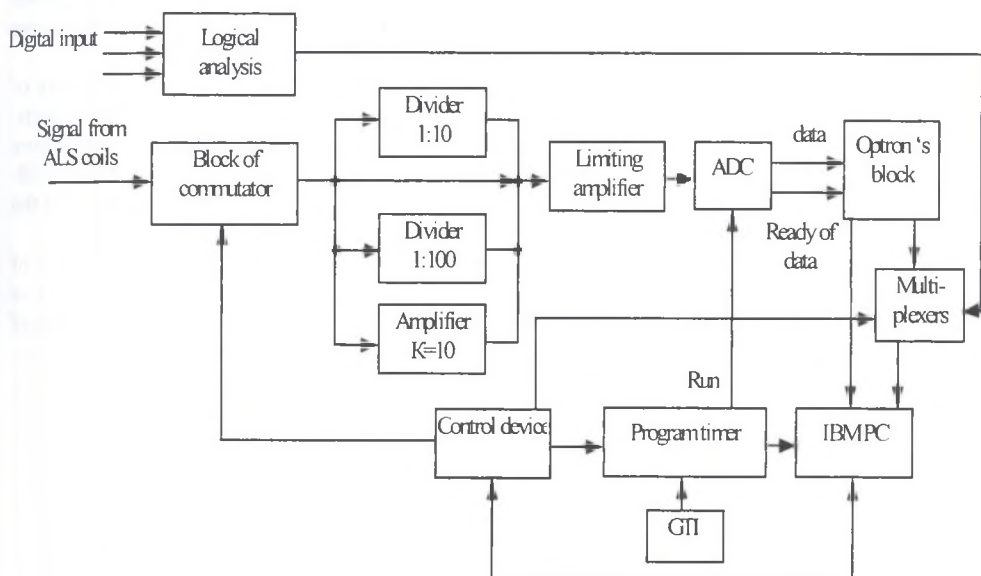


Fig.3. Structure scheme of device for the checking of code current parameters

Ten-digit ADC of serial approach has input range $\pm 5V$ and will transform an analog signal to a digital code with a step of quantization $\pm 5mV$. The maximal ADC discretization frequency is 40 kHz that it is quite enough for realization of the spectral analysis of a current flowing in rails. The differential error makes no more than 0,1 %. Also there is possibility to use twelve-digit ADC.

The programmed timer is intended for the definition of discretization frequency of input signal. The interval of discretization can be changed in wide range from 25 microseconds up to 70 minute (bottom limit of discretization frequency is limited to properties of ADC, and top - timer and divider of frequency). The program timer produces the frequency of signals. They is stabilized by the quartz resonator on 1 MHz.

The control device consists of the registers of the data and operation, which are necessary for the task of operations of the program timer, multiplexers and also block of commutator.

The block of commutator is needed for a dependence of a voltage range of input analog signal. It consists of a some small-sized relays, transmitting a signal on the limiting amplifier or through a divider (1:10 and 1:100). It is allowed to increase an input diapason of voltage up to 500V. Thus, the given device can be used for recording a signal not only from inductive coils of ALS, and from other detectors not situated on the locomotive, and connected to a rail circuit, feeder of return tractive current (for the amplitude and spectral analysis of interference flowing in rail circuits). Also input signal can be amplified with the help of the operational amplifier in 10 times. That is necessary for recording signals from coils automatic locomotive signal system in a range from 0 up to 500 mV. That expands area of application of the given device.

The limiting amplifier is intended for restriction of an ADC input from voltage at a level 5,5 V. It provides high input resistance of a hardware-software complex to prevent influence of measuring system on work devices of automatics and telemechanics.

The optron's block is necessary for increase protect from interference and reliability of work of measuring system. It provides galvanic division between analog and digital parts. There is pulse interference in rail circuit sometimes. At the use galvanic division the failure take place only in ADC circuits that is some choices of data will have limiting value 5,5B. After disappearance of a interference the device will begin to work in a normal mode, and the arisen of its is traced by program.

The measuring device connects to the PC through parallel port (LPT). The block of multiplexers has 16 inputs and needs for the conformation of ADC with the LPT-port of computer. That gives possibility to control up to 6 digital signals transmitting on an input of the logic analyser simultaneously, which supervises presence of a code.

4. ALGORITHM OF FUNCTIONING OF DEVICE

Algorithms of processing signal by the device for the checking of parameters of code current on the hardware and software levels are given on a Fig.4.

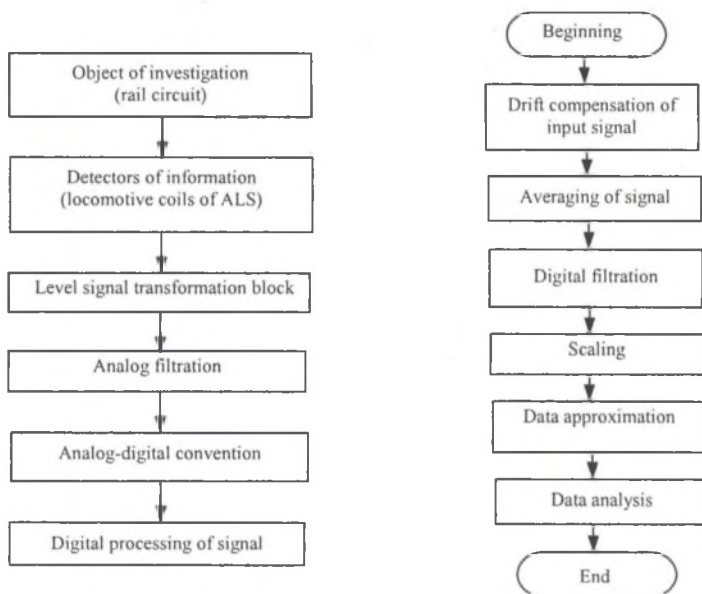


Fig.4. Algorithms of processing of a signal at a hardware and software levels

The discretization frequency of input signal records in the program timer before the beginning of processing of a signal. The program timer gives command "start-up of signal transformation". It develops with the given interval. On ending transformation ADC gives out a command "readiness of data", that causes hardware interruption of LPT port of computer. The subprogram of processing of interruption carries out reading the data from the ADC into the buffer of the computer's RAM.

The digital processing of a signal and analysis of the data is carried out with the help of special program. Its algorithm is shown on fig.4.

The drift compensation of input signal allows to exclude of an error which is brought in by the interface block of the hardware and influence of voltage of displacement of the input cascade of a measuring complex (operational amplifier and ADC).

The signal averaging is used at the analysis harmonic signals. It calculates a spectrum of a signal not on one sample, and on several. Result averages. If it is necessary to investigate pulse interference, the averaging block is excluded by program.

The procedures of digital filtration of signal are included in structure of the software. There is frequency way of filtration on the base of Fast Fourier Transformation. Early there is analog filters. It is known that the digital filters has the following advantages in front of analog: the high stability of discretization frequency (this property is realized at a hardware level and is caused by the application of the quartz generator), simplicity of reorganization frequency the characteristics, possibility of realization of several types of filters at once.

The scaling allows to transfer a digital code in values of a real signal of controllable parameter. That is necessary for check of correctness of transformation of a signal and for preparation of a signal for the analysis.

The approximation. For the processing of written signal there is possibility to apply or subprogram of linear or splay approximation for reception of intermediate results between samples. The linear approximation has smaller accuracy, but it allows to process the large data files with high speed and can be used for a tentative estimation measurement results and at the analysis given without the high requirements to accuracy. The precision data can be received with the help splay approximation, but it requires the large computing opportunities.

The graphic part is intended for realization of the man-machine interface and management of processes of digital processing of a signal, analysis of the data and management of the hardware of a measuring complex and was described in [2].

The driver LPT port is necessary for an exchange of the information between the PC and hardware of a measuring device. Use of the given driver allows to function to the software under operational systems Windows-98 or -2000. It gives possibility to connect the registers of parallel port and to carry out processing hardware interruptions acting from ADC.

The hardware-software complex provides executing of the following functions: measurement and check on conformity to the requirements numerical and time parameters of code current, definition of the parameters of rail circuits and asymmetry of code and tractive current in rails (at the recording of signals from ALS coils separately), calculation of amplitude- and phase-frequency characteristics of code and tractive current, saving up to 10 million samples, probability and statistic processing of measurement signal, distribution of the recommendations concerning a deviation of code signal from norms and as for their elimination.

5. MEASUREMENTS

The given measuring device allows to record a signal from an output(exit) of the filter, as it is required the maintenance Manual of devices of the signal system, centralization and block the check of work of devices automatic locomotive signalling system (ALS), and as locomotive coils. Results of measurement: view code signal of type "green" in mode of oscilloscope and their spectrum analyse is given on a Fig.5. This signal was record from the locomotive coils on the railway section of direct current near tractive substation. Deviation in the numerical and time parameters of code current was not detected. But you can see high level of interferences in the return tractive current by frequency of 600, 1200, 1800 and 2400Hz, which are caused by the work of 12-pulse rectifier.

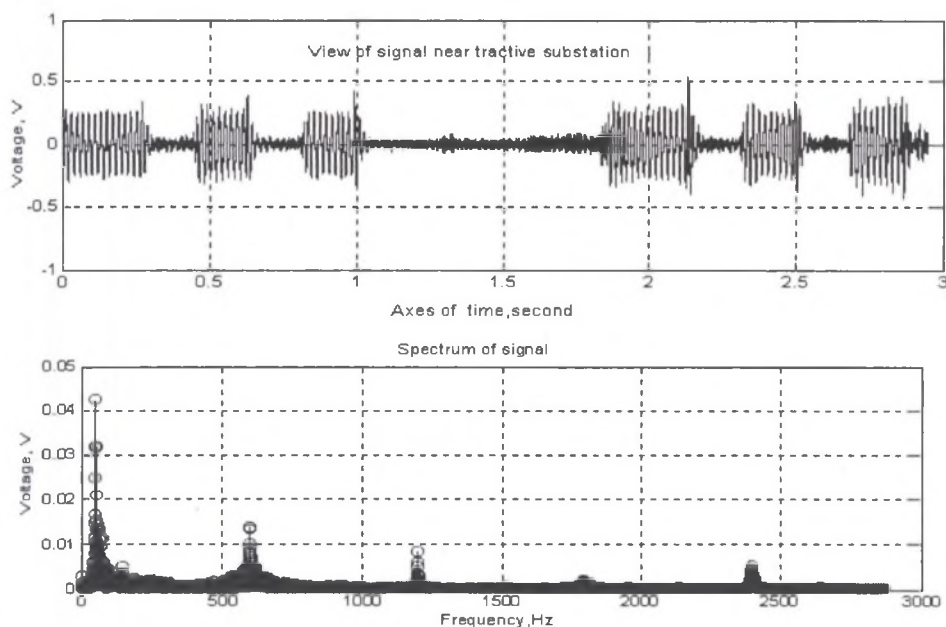


Fig.5. Results of measurement: view code signal of type "green" in mode of oscilloscope and their spectrum analyse

6. CONCLUSIONS

The hardware-software complex for the check of parameters of a code current in rails is developed. The given device is multifunctional, as allows not only to define parameters of currents and rail circuits, and to carry out the analysis of an electromagnetic situation on the given railway section and also to determine a spectrum of interferences flowing in a rail circuit. The measurements can be realised on the basis of working cars - laboratory, by recording a signal from reception coils, and on railway section at connection of the equipment to a rail circuit or feeder of return tractive current.

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