UDC 621.331 **DOI: 10.31388/2220-8674-2019-1-6**

THE AUTOMATED METHOD OF CHECKING THE TRACK CIRCUITS PARAMETERS

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Summary - the automated method of measuring parameters of code current and primary and secondary parameters of track circuits were elaborated. The mathematic model of automatic locomotive signaling system channel was improved and it is considered in this paper. The algorithms of definition of parameters of track circuit are offered.

Keywords **– track circuit (TC); measurement; code current; track circuit parameters; amplitude; time parameters of codes; traction current, harmonics**

INTRODUCTION.

There are six Railways in the Ukrzaliznytsia. The Pridnyprovska Railway has railway sections at the 3 kV d.c. traction (93.3 %) and autonomous (diesel) traction (6.7 %). It was founded since 1873 year. The length is 3275 km. The Pivdenna (Southern) Railways has railway section at the 25 kV a.c. and at the 3 kV d. c. traction (33.5 %) and autonomous traction (64.5 %). Their length is 3000 km. It was founded from 1868. The Pivdenno-Zakhidna (Southen-West) Railway was founded since 1870. Their length is 4668 km. There are railways at the 25 kV a.c. traction (35%) and autonomous traction (65 %). The Lviv Railway has 4521 km and it was building in 1861. It is more oldest from all Railways of Ukrzaliznytsia. It has all kinds of traction system. The 3207 km (71 %) from all length of Lviv Railway is equipped by the electric traction. There were electrified 469 km of railway lines at the 25 kV a.c. traction with shielding and powering wires. The Odessa Railway has near 4000 km. There are sections at the 25 kV a.c. traction (1708 km or 41 % from all) 3 kV d.c. traction (1.6 km) and diesel traction (2492 km or 59 %). It was built in 1865. Since 1997 it was electrified 63 km of lines by the a.c. 25 kV 50 Hz. Since 2015 the Donetsk Railway has 1616.7 km instead 2861.8 km and 639 km (40 %) is electrified by the d.c. traction from it predominantly.

It was electrified 1571 km of railways: 1184 km at te a.c. traction (Lviv, Pivdenno-Zakhidna, Pivdenna, Odesaa Railways) and 387 km at the d.c. traction (Donetsk, Pivdenna, Lviv Railways) since 1997 year and to the present time. So 47 % (10500 km from total length 22300 km) is railways by the a. c. traction of 25 kV 50 Hz (5500 km) and d. c. 3 kV (5000 km). Last time (1991 – 2018 years) the electrification of railways were carried out by the a. c. 25 kV 50 Hz.

The automatic locomotive signaling (ALS) system and automatic block systems use to transfer of the codes to the locomotive and receiving apparatuses of track circuit and to regulate traffic of trains on the railway sections. To transmit codes by the ALS canals (rail lines) it is applied signals at the 50 Hz frequency for railways with d. c. electrical traction and signals at the 25 and 75 Hz for a. c. electrical or autonomous traction. Also there are code and tonal track circuits (TTC) to control traffic of trains on railways of Ukraine. It was equipped 5200 km without isolative connection (known also as “velvet track”) since 2010. It is meant to applied of tonal track circuits TTC3 at the 420, 480, 580, 720, 780 Hz and at the modulation 8 and 12Hz frequencies, for example[1 – 6].

The code track circuits (TC) are the transferring channel of codes automatic locomotive signal system from track-devices to the locomotive. And they are a primary element directly determining safety of trains’ movement and they check integrity of rails [1]. The investigation of parameters code current and spectrum of traction current is necessary to control in pause of code at the using of method, which is assumed to measure with the help of special device of car-laboratory „Automatics, telemechanics and communication”. In given case it was carried out by the record of signal from one or two inductive coil of locomotive, which moved on the railway section. In result we able us a possibility to determine as the parameters of code current, flowing in rails and spectrum composition of return traction current, as the parameters of track circuits [2-5].

It is needed to elaborate method of automated measurement parameters of track circuits and harmonics of return traction current. It is allowed us to take into account different sources of electromagnetic influences. Most perspective from other method is automated measurement method on the base of car-laboratory because it will allow us to proceed from scheduled preventive maintenance to repair on a status of object and to reduce number or staff and to raise safety of movement of trains.

The development of automated method of measurement parameters of TC and harmonics of return traction current from car-laboratory is an actual. To solve of this task it is necessary to develop of mathematic model of track circuit, which was worked in mode of occupancy by train (mode of automatic locomotive signaling (ALS)), to use the formula of electromotive force (EMF) of inductive coils of locomotive [9, 10], to create algorithms of determination of the track circuit serviceability and parameters of code current.

MATHEMATIC MODEL OF THE ALS CHANAL.

The equipment of car-laboratory uses for the definition parameters of code current in rails during measurement travel two times in year usually. The experimental data can be given with the help of special elaborated measuring system [6, 7], based in the car-laboratory for the control of parameters of code current. So there is a continuous communication between track and locomotive devices in the ALS system. The coils are situated before first wheel pair of locomotive and connect inductively with the current in rails, by the means of a magnetic field, series and towards each other (fig.1). Magnetic field is formed around of rails by the alternating code current. Thus, there is a separate channel of communication within the limits of each track circuit.

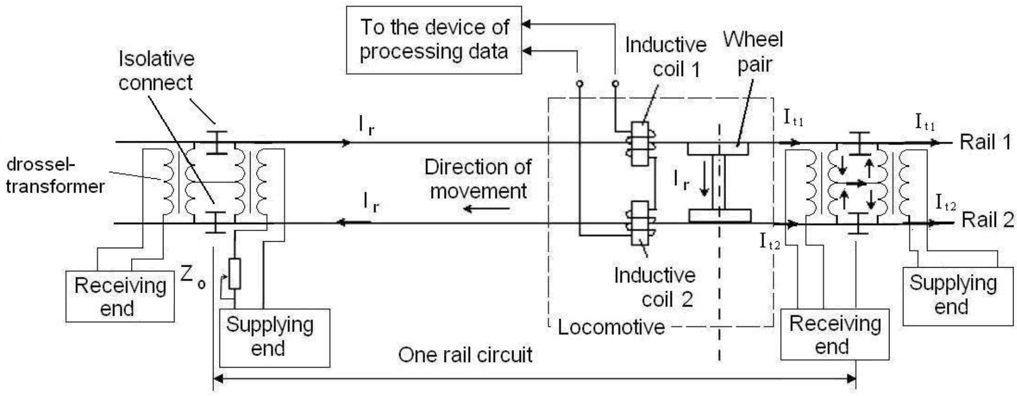

Fig. 1. Structure scheme of data transferring canal to the locomotive

For the definition of parameters of track circuit we used the equivalent scheme, given on the fig. 2. This scheme includes supplying end, rail lines and receiving end, each from which are four-poles accordingly. Four-poles of supplying and receiving end include intermediate and protective apparatuses, and four-pole of rail lines consist of only rails, connected with the help of electrical connections.

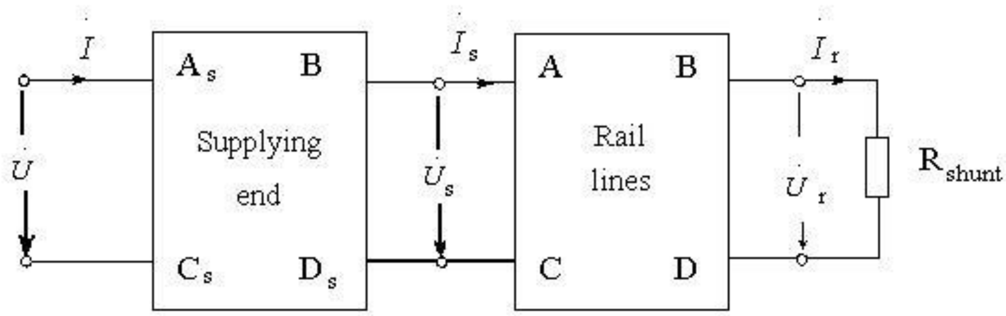

Fig. 2. Equivalent scheme of track circuits at the present train shunt on the receiving end

According with the theory of four-poles write system of equation of voltage and current in the begin of track circuit:

$$\begin{cases} \dot{U}_s = A_{sh} \times \dot{U}_r + B_{sh} \times \dot{I}_r \\ \dot{I}_s = C_{sh} \times \dot{U}_r + D_{sh} \times \dot{I}_r \end{cases}, \quad (1)$$

where $\dot{U}_s$, $\dot{I}_s$ – voltage and current in the begin of track circuits (supplying end),

$\dot{U}_r$, $\dot{I}_r$ – voltage and current in the end of track circuits (in the point of putting train shunt),

$A_{sh}, B_{sh}, C_{sh}, D_{sh}$ – coefficients of rails four-poles in the regime of automatic locomotive signalling.

Coefficients of rails four-poles in the regime of automatic locomotive signalling are equal:

$$A_{sh} = 1 + \frac{\bar{Z}}{R_{sh}}, \; B_{sh} = \bar{Z}, \; C_{sh} = \frac{1}{R_{sh}}, \; D_{sh} = 1, \quad (2)$$

where $\bar{Z} = \bar{z} \cdot l$ – impedance of rail line, Ohm,

$\bar{z}$ – specific impedance of rail lines, Ohm/km,

l – distance between supplying end and locomotive, km,

R_{sh} – resistance of train shunt,

$R_{sh} = 0,06$ Ohm.

So knowing value of current in the begin and end of track circuit and voltage on the outputs of generator, which should be equal minimal voltage of way’s transformer $\dot{U}_s = \dot{U}_{\min}$ and can be taken from regulative tables [4], we are allowed to define impedance of rail lines

$$\bar{Z} = \frac{\dot{U}_{\min} - \dot{I}_r \cdot R_{sh}}{2 \cdot \dot{I}_r}, \quad (3)$$

The wave impedance and propagation coefficient are equal [3, 9]:

$$\bar{Z}_v = \sqrt{\bar{z} \cdot R_{is}}, \gamma = \frac{arcsinh(\sqrt{\bar{Z}_v R_{sh}})}{l} \quad (4)$$

where R_{is} – equivalent resistance of isolation of rail line and grounding of supports of catenary, Ohm·km.

Thus, the resistance of isolation of rail line can be defined as

$$R_{is} = \frac{\bar{Z}_v^{\,2}}{\bar{z}}. \quad (5)$$

So, knowing the value of current in the begin and end of track circuits in the results of measurements with the help of equipment, established in the car-laboratory, and taking value of generator's voltage from regulation tables we can define primary and secondary parameters of track circuits

We have obtained the equation of EMF induced in the coils of ALS, which takes into account the wave delay effect, which occurs in tonal track circuits of high frequency and high-frequency noise. The resulting relationship between the current ALS and EMF can be used to determine the parameters of the code current by using the proposed hardware and software measuring complex, in which sensors are information locomotive coils [7, 9, 10].

DEFINITION OF TRACK CIRCUIT PARAMETERS.

The designed hardware and software measurement system can record the signal from the output of the filter of the ALS system, as required by the instructions for maintenance of signaling, centralization and blocking devices [1], and the outputs of the receiving coils. Signal recorded by the receiving coils of ALS, is the amount of code signals from ALS and traction current with all its harmonics, and transients that occur during operation of the locomotive. And therefore, this device allows us to analyze not only the temporal and amplitude parameters of codes of ALS, but also assess the impact of noise on the automation systems and analytically determine their cause.

It is proposed to use following method for the definition of parameters of track circuit from car-laboratory. The technique of control of the parameters of track circuits from car-laboratory includes measurements, which performed by two electromechanics. The measurement system of parameters code ALS was checked in laboratory (Fig. 3).

It is necessary to calibrate the apparatuses of car-laboratory on the base of real track circuit before measurement. It is important that track circuit work in mode of occupying by rolling stock. Thus it checks the conformity of results of measurement, carried out by the developed apparatuses, to data was given directly in the track circuit at the measurement of code current. Next step is the definition of original data of investigated section: or station, the name of railway section, length and type of TC, the sampling frequency settings and the quantization step, which used at the analog-to-digital conversion of the signal. Developed apparatuses was established in car-laboratory (Fig. 4).

As a result, the number of parameters controlled from car-laboratory, equipped with the developed hardware and software apparatuses, expands. The method of measurement parameters track circuits is proposed in [6, 7]. It is based on the comparison a measuring data with the theoretical characteristics, corresponding normalized functioning of TC.

Further actions of operator-electrician are the observations of work of equipment. Reading the data from the inductive coils and checking of parameters of TC and code current is carrying out automatically. At the same time the monitoring of levels and spectral composition of current in rail lines are done to identify their and to remove the reasons of their appearance. According to the results of control of parameters of track circuits is created a database that allows us to automate the process of finding of TC with faults and predict their causes.

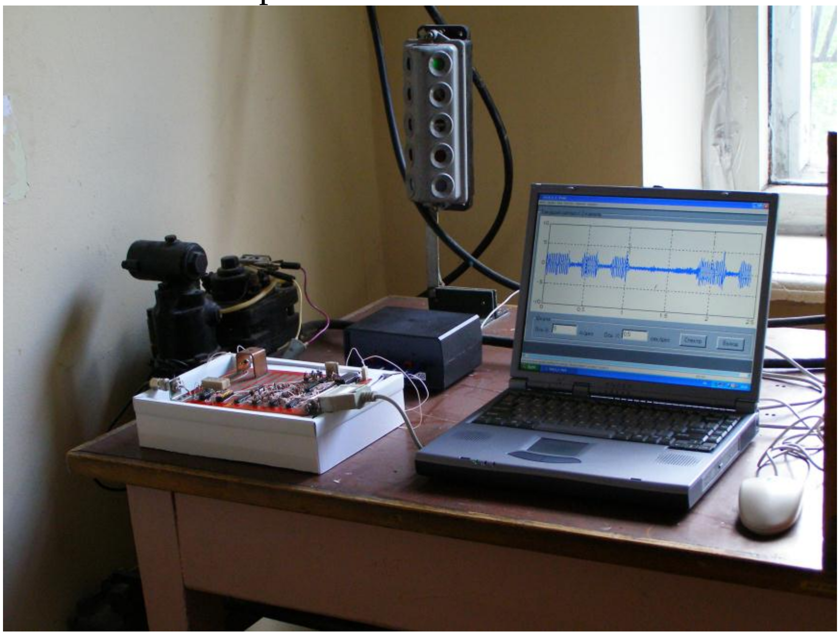

Fig. 3. Test proposed measurement system of parameters code ALS in laboratory

Fig. 4. Work place of electrician of car-laboratory "Automatics, telemechanics and communicaion" and results of measurements of code and return traction currents

As a result, the time spent on the control parameters of TC will be reduced, the working conditions of personnel will be facilitated l and the subjectivity in the measurement will be excluded.

At the determining the types of code signals received from the track circuits, we solve such problems: measurement of the pulse duration and pause with the exception of sags and surges of a signal; selection of the type of code by the pulse duration and pauses; determining the type of the code received from the track circuit and the type of the code track transmitter; definition of amplitude and time parameters of the code signal.

To solve the first problem were taken signatures of pulses and pauses when a signal with an amplitude greater than or equal to $0.6U_n$ for at least 0.2 s is recognized as a useful signal, and the signal with an amplitude of less than or equal to $0.4U_n$ for at least 0.1 s - as the pause. The value $0.6U_n$ is the minimum value that will be recognized as a useful signal when the system is the automatic locomotive signaling. To calculate the duration of pulses and pauses the software timers are used. Algorithm for determining the duration of the pulses and pauses is shown in Fig. 5.

In addition to determining the duration of the pulses and pauses, also their adjustments are made, designed to prevent a momentary signal. For example, if short-term loss of signal during the determination of the pulse duration the pause timer can start. If a signal for 0.1 seconds is not recovered, the pause counting continues, but as the pulse timer has not been disabled, then after stop the pulse timer the pulse correction is carried out (the subtraction of the pulse duration by 0.1 s). A similar process is organized during the determination of the pause in the event of a pulse.

To solve the second problem and determine the type of message frame and code track transmitter (CTT) all pauses and pulses were divided into certain types (P1 – P7, I1 – I7). The combination impulses and pauses of codes is accorded type of codes: “Red-yellow”, “Yellow”, “Green” for different code track transmitters KPTSH-5 and TPTSH-7.

To solve the third problem, and determine compliance with the requirements of the decrypted code signal amplitude was also been developed appropriate software. Automated measurement hardware and software package calculates the duration of the pulses and pauses in the message frame and therefore can determine what type of code track transmitter is used in this track circuit. It is known that, when a stage is equipped with automatic lock-haul code system, each signaling point is an alternation of code track transmitters, which allows for protection against dangerous failures on short-circuit block joints separating the track circuits. Therefore, it is possible by changing one code track transmitter by another one to determine the location of insulation junction.

For validation of the coordinates of the insulation junction we need to check for compliance with the calculated length l_{TC_i} of the i-th track circuit with an error of 3 % to the actual value. Coincidence of the real and the measured length matches the TC working condition of isolating joints, different – is faulty. Data correction means specification of the measured TC length in mind that the type of CTT is determined only after deciphering code of three parcels from one type of CTT. Therefore, the length of the track circuit is subtracted the measured distance traveled by the train during the decoding of the three code packages. Algorithm for computing the length of RC and definition isolating joints fault is shown in Fig. 6.

Algorithm for checking the status of the track circuit involves determining the state of the track circuit and it is carried out on the current curve of the locomotive signaling $I(x)_{\text{meas}}$ depending on the coordinates obtained from the measurements.

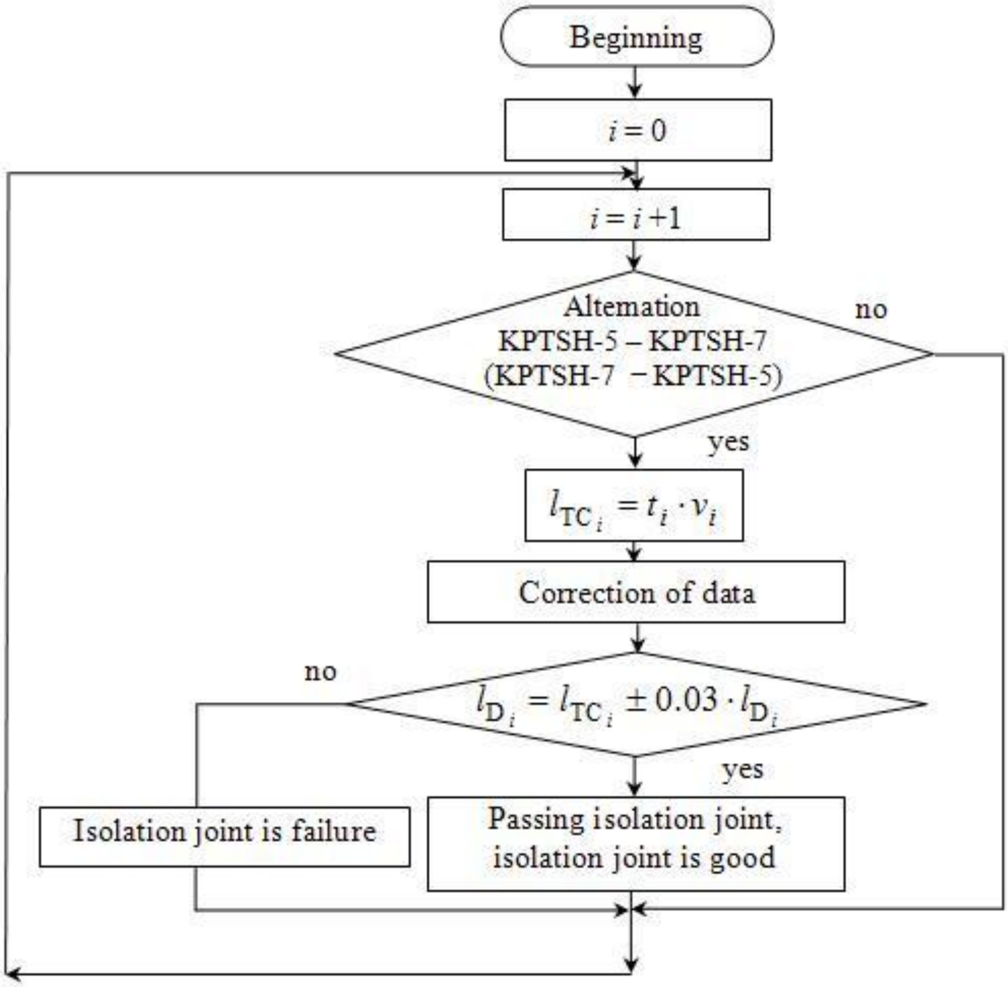

Fig. 5. Algorithm for determining the duration of the pulses and pauses

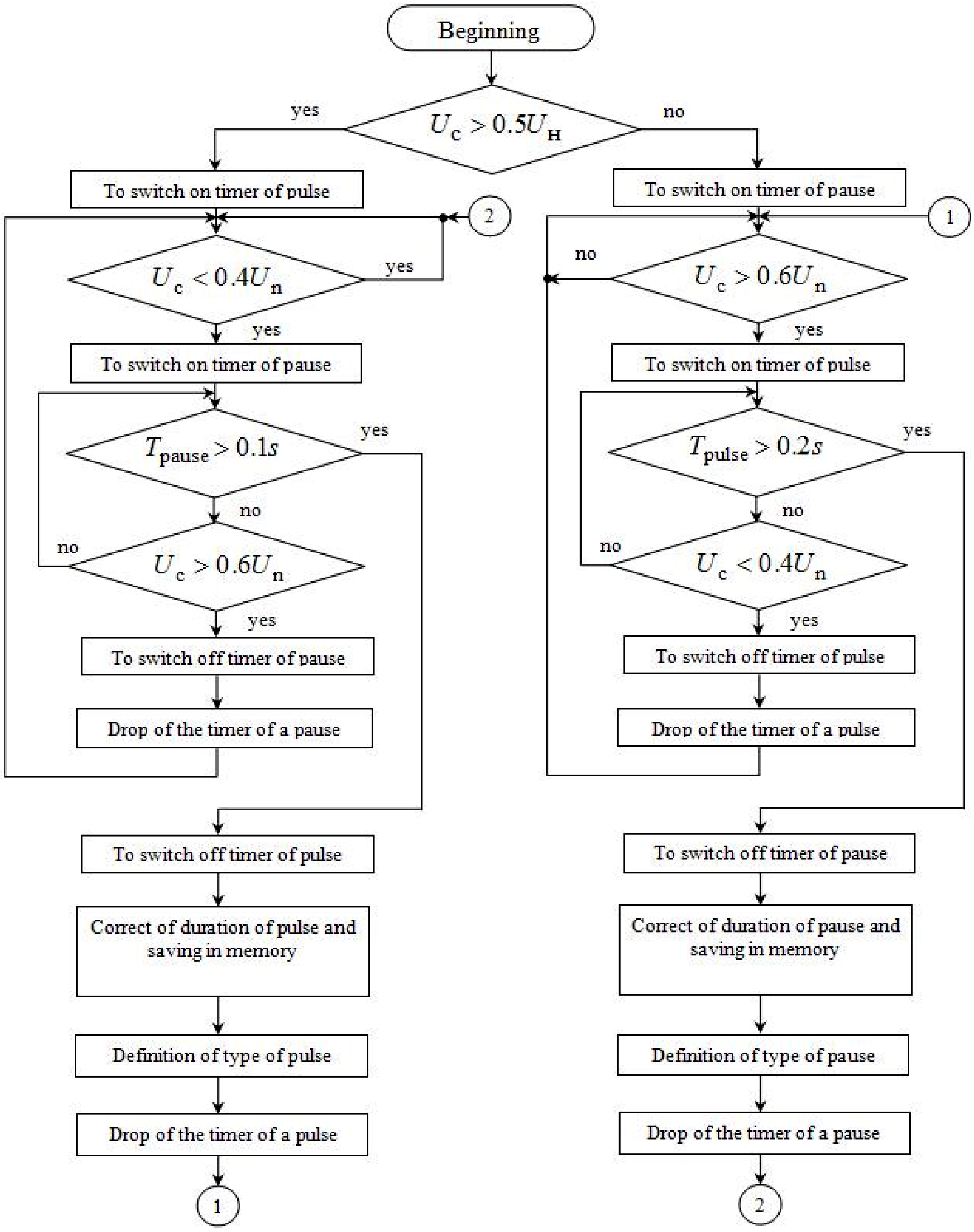

Fig. 6. Algorithm for determining the length of the track circuit and serviceability of block joints

Evaluation is done by comparing the measured code current curve $I(x)_{meas}$ of ALS with calculated $I(x)$ at nominal operating conditions of the track circuit (for example, the impedance of the rails Z1 = Z2 = 0,8e^{65j} Ohm / km with welded copper connectors, the frequency of the current signal of 50 Hz, the conductivity of insulation Y1 = Y2 = 0 5 S / km) and given its length. Appearance of break points of the first kind in the current curve $I(x)_{meas}$ of locomotive signaling indicates an open rail connectors at this point. Underestimated the value of ALS current $I(x)_{meas}$ compared with the calculated value indicates an undervalued ballast impedance.

The ocsillogram and spectrum of "Green" code at the 25 Hz and at the autonomous traction are given in Fig. 7. After measurements all data are processed. There are interferences in the dividing pause of code. The reasons of appearance interferences are power system and current of traction motors.

The resulting databases are created. This allows us to observe the results of measuring the current of locomotive signaling along the length of each track circuit. The shape of the ALS current curve and other parameters determined during the measurement of the trip. It also creates a database, which indicates the number of TC, which revealed the following variations: the amplitude at the beginning of TC, which is below the minimum value; the time parameters of the code, which does not confirm to requirement; the underestimated impedance of ballast; break of electrical connectors.

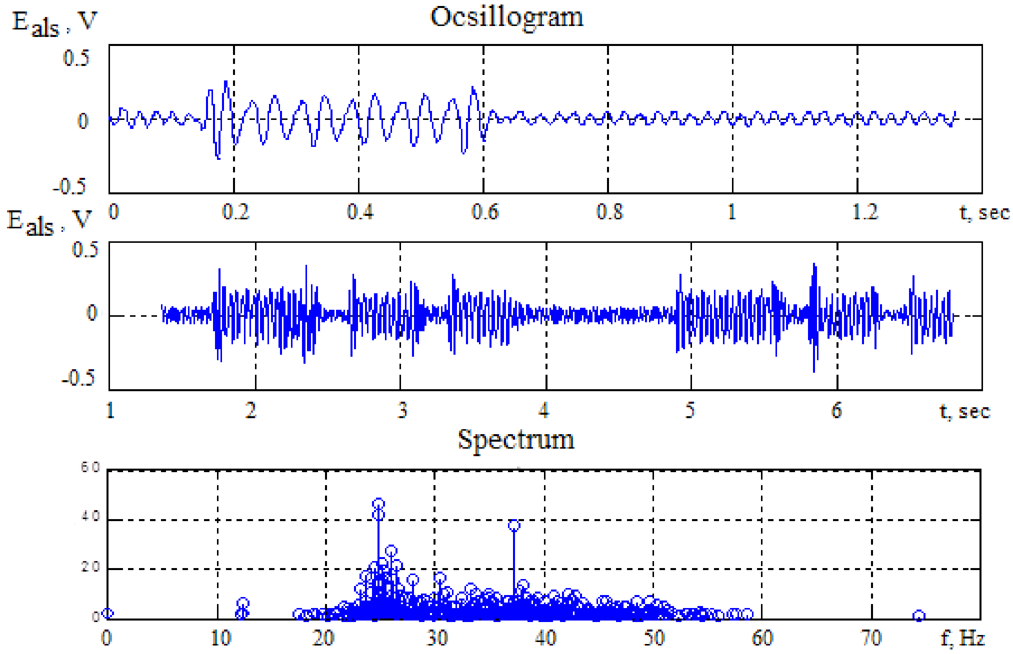

Fig. 7. Ocsillogram and spectrum of code of track circuit at the 25 Hz and at the diesel traction recording from ALS coils at the measuriment trip of car-laboratory

CONCLUSIONS.

The method for definition of parameters of TC and harmonics of return traction current was elaborate. This method and hardware-software apparatuses allows you to define by the EMF induced in the one or two receiving coils, which is proportional of current in rails. So, we are determined the following quantities: the magnitude of the code current for the entire length of the track circuit, the duration of the pulses and pauses for all parcels of code, the type of code signal and the type of CTT, coordinate, the length of the TC, serviceability of insulating junctions and electrical connectors. The results of measurements of EMF induced in each of the receiving coils apart, the spectral composition of the noise occurring in the traction network, and harmonics amplitude and impulse noise, the causes of noise in the rail net can be revealed. The test of given measuring apparatuses was executed on the base of car-laboratory „Automatics, telemechanics and communication” of Pridneprovsky Railway of Ukrzaliznytsia.

The application of proposed method of control parameters of TC from car-laboratory will reduce service time and allowed us to change a type of TC’ maintenance to the service as an object in further.

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АВТОМАТИЗОВАНИЙ МЕТОД ПЕРЕВІРКИ ПАРАМЕТРІВ РЕЙКОВИХ КІЛ

Сердюк Т., Кузнецов В., Сердюк К., Ніколенко А.

Анотація - розроблено метод визначення параметрів кодового струму і гармонік зворотного тягового струму, а також первинних і вторинних параметрів рейкових кіл. В статті представлено удосконалену математичну модель каналу системи автоматичної локомотивної сигналізації, яка стала науковим обґрунтуванням для розробки автоматизованого методу перевірки параметрів рейкових кіл. Розроблені алгоритми визначення параметрів рейкових кіл.

Запропонований метод обслуговування рейкових кіл полягає у записі і подальшому аналізі сигналу, отриманого з приймальних котушок вагону-лабораторії (або індуктивних котушок автоматичної локомотивної сигналізації). Сигнал є пропорційним електрорушійній силі (ЕРС), яка індукується в приймальних котушках і пропорційна струму в рейках (кодовому і зворотному тяговому). Розроблено апаратно-програмний комплекс, який дозволяє визначити такі величини: величина струму коду по всій довжині рейкового кола, тривалість імпульсів і пауз для всіх посилок коду, тип кодового сигналу і тип кодового колійного трансмітеру (КПТШ), координату, довжину рейкового кола, справність ізостиків і електричних з'єднувачів, первинні та вторинні параметри рейкових кіл. Апаратно-програмний комплекс дозволяє виміряти ЕРС, індуковану в кожній з приймальних котушок, визначити спектральний складу завад у зворотному тяговому струмі, імпульсні завади, а також проаналізувати причини їх виникнення. Апробацію запропонованої методики і апаратно-програмного комплексу було здійснено на базі вагону-лабораторії «Автоматика, телемеханіка та зв'язок» Придніпровської залізниці Укрзалізниці.

Застосування запропонованого методу контролю параметрів рейкових кіл з вагону-лабораторії «Автоматика, телемеханіка та зв'язок» дозволить скоротити час, який витрачається на обслуговування рейкових кіл і у подальшому змінити вид обслуговування рейкових кіл з планово-попереджувального на обслуговування «за станом об'єкта».

Ключові слова – рейкове коло, вимірювання, кодовий струм, параметри рейкових кіл, амплітуда, часові параметри кодів, тяговий струм гармоніки.

АВТОМАТИЗИРОВАННЫЙ МЕТОД ПРОВЕРКИ ПАРАМЕТРОВ РЕЛЬСОВЫХ ЦЕПЕЙ

Сердюк Т., Кузнецов В., Сердюк К., Николенко А.

Аннотация - разработан метод определения параметров кодового тока и гармоник обратного тягового тока, а также первичных и вторичных параметров рельсовых цепей. В статье представлены усовершенствованную математическую модель канала системы автоматической локомотивной сигнализации, которая стала научным обоснованием для разработки автоматизированного метода проверки параметров рельсовых цепей. Разработанные алгоритмы определения параметров рельсовых цепей.

Предложенный метод обслуживания рельсовых цепей заключается в записи и последующем анализе сигнала, полученного с приемных катушек вагона-лаборатории (или индуктивных катушек автоматической локомотивной сигнализации). Сигнал пропорционален электродвижущей силе (ЭДС), которая индуцируется в приемных катушках и пропорциональна току в рельсах (кодовому и обратному тяговому). Разработан аппаратно-программный комплекс, который позволяет определить следующие величины: амплитуда кодового тока по всей длине рельсовой цепи, длительность импульсов и пауз для всех кодовых посылок, тип кода и тип кодового путевого трансмиттера (КПТШ), координату, длину рельсовой цепи, исправность из-за стыков и электрических соединителей, первичные и вторичные параметры рельсовых цепей. Аппаратно-программный комплекс позволяет измерить ЭДС, индуцированную в каждой из приемных катушек, определить спектральный состав помех в обратном тяговом токе, импульсные помехи, а также проанализировать причины их возникновения. Апробацию предложенной методики и аппаратно-программного комплекса было осуществлено на базе вагона-лаборатории «Автоматика, телемеханика и связь» Приднепровской железной дороги Укрзализныци.

Применение предложенного метода контроля параметров рельсовых цепей с вагона-лаборатории «Автоматика, телемеханика и связь» позволит сократить время, затрачиваемое на обслуживание рельсовых цепей и в дальнейшем изменить вид обслуживания рельсовых цепей с планово-предупредительного на обслуживание «по состоянию объекта».

Ключевые слова **-** рельсовая цепь, измерения, кодовый ток, параметры рельсовых цепей, амплитуда, временные параметры кодов, тяговый ток гармоники.