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Method for calculating the coefficients of intelligent sensors of automation in transport

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Abstract: In the analysis and synthesis of intelligent sensors, the general theory of track circuits can be mainly used. However, it is necessary to take into account some features due to the lack of insulating joints and the use of a microprocessor system. Calculations of the coefficients of intelligent sensors were carried out with a number of assumptions and no methodology was given for their exact determination. In the studied case, to obtain precise analytical expressions, it is necessary to consider sensors in which seamless track circuits are used as asymmetric unlimited track tracks, in which, firstly, the operating modes of the main and secondary parameters will differ significantly from each other and, secondly, the train set can be located along the adjacent track circuits. The article discusses the basic equations that allow taking into account the features associated with the absence of insulating joints in the analysis and synthesis of intelligent track circuits.
Keywords: sensors, intelligent sensors, mathematical model, rail circuit, jointless track circuit

1. Introduction

Based on the data of the development of the analysis of the theory of track circuits taking into account the distribution and propagation of signals along the track lines, it is necessary to take into account the parameters of distribution and losses, for example, attenuation, in one of the steady-state modes, this is the main definition of the theory of track section monitoring sensors [1]. To derive a mathematical model of a track section sensor, it is necessary to imagine a track line in a certain form, i.e. to draw up an equivalent circuit, but for a more in-depth study it is necessary to imagine a four-pole equivalent circuit, taking into account grounding along the path of signal voltage transmission [2; 3]. To determine the shunt and control mode, it is necessary to take into account the dissimilarity of the track circuit monitoring sensor, especially when the shunt is not felt and a rail break has occurred [4]. To solve the problem, it is necessary to analyze the track circuit for a certain situation, and from here derive a mathematical model of the track circuit behavior, and for this it is necessary to determine the accuracy of the electrical parameters of the sensor from the insulation resistance, changes in conductivity and the state of the insulating joints, as well as the resulting interference of the train, grounding of power lines, study the parameters of change in wide ranges, create algorithms for simplifying calculations and develop a simulation model for an intelligent track section monitoring sensor. Take into account the modeling of various types of sensors, station and line, with insulated joints and without insulated joints [5-11; 13]. Therefore, combining all the requirements, come to the conclusion that most of these requirements are contradictory, a successful compromise satisfaction of these requirements in some problems may be far from optimal in others [12]. Making a general coverage for the same track circuit, it is necessary to have not one, but several models. For example, track circuits with the property of transverse symmetry are appropriately analyzed by two-pole equivalent circuits, and in the case of traction current asymmetry, it is necessary to use four- or multi-pole equivalent circuits. In this regard, this multiple classification of various models must be carried out according to a variety of features in order to describe all possible cases [14-18].

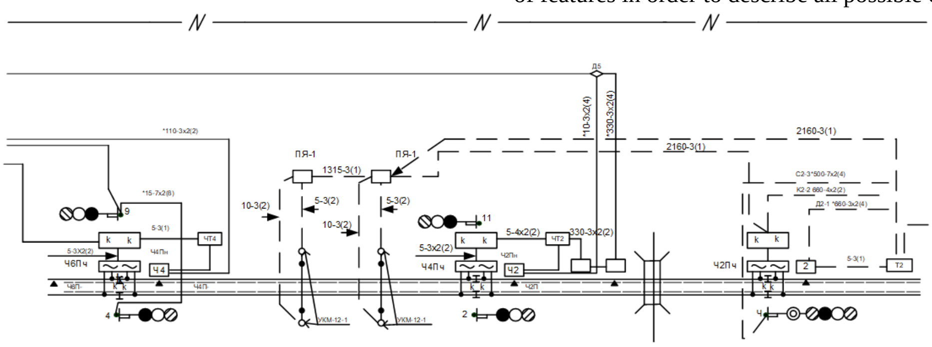

Fig. 1. Scheme of the track section

In many countries of the world, track circuits are the main element of modern train control systems. On railways, they serve as an informant about the state of the track, as well as a telemechanical channel [3, 19]. To conduct the study, a simulation model of a jointless voice-frequency track circuit was created, and the relay-based track receiver was replaced with a microprocessor-based track circuit [22-25]. The study uses the track section in Fig. 1. Therefore, for such a track circuit, a transition to an intelligent sensor for determining the moving unit is carried out. With the proposed method,

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the parameters of the operating modes of track circuits should be taken into account and developed, therefore, analysis and synthesis should be carried out, mathematical modeling should be carried out and analytical expressions for intelligent sensors should be derived. Thus, to designate and investigate the energy efficiency and power consumption of the track control sensor.

For the analysis and synthesis of sensors without insulating joints, first of all, it is necessary to derive equations for calculating the coefficients of a four-pole network replacing a rail line [1; 2].

The coefficients of a fourpole sensor (JTC) can be determined based on equations taking into account the distribution of resistances to the diagram in Fig. 2 that differ from those adopted for track circuits with insulating joints [3; 9; 12].

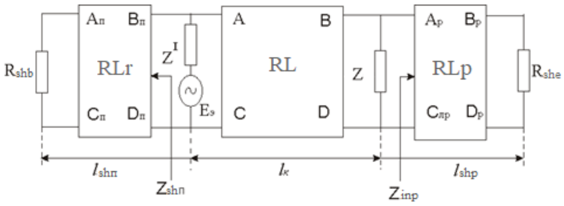

Fig. 2. General equivalent circuit of a sensor

Comparing the scheme shown in Fig. 2. with the main equivalent circuit of sensors with insulating joints (TC), it can be argued:

1. The track circuits with insulated joints used on the railway operate in modes that differ significantly from those of continuous track circuits, and their equivalent circuits are different for analysis and calculations, so it is advisable to use a four-pole equivalent circuit for continuous track circuits and simulate the calculations of the coefficients of continuous track circuits [4; 11].

2. In normal mode, due to the lack of insulating joints, current spreading along adjacent rail lines will require an increase in the value of Ee, which will ultimately increase the value of Krmax and reduce the values of Ksh and Cor [5].

3. The normal mode of operation of the RLn track circuit will be observed not only when all the rail lines are free, but also if one of the adjacent rail lines is occupied by a moving unit, and its shunt will be removed from the point of connection of the track circuit equipment at a distance greater than. The section ldsh is called the zone of additional shunting. These zones are located both at the supply line and at the relay line ends of the track circuit. When two trains approach each other, the normal mode of operation of the RLn track circuit will depend on the presence of train shunts in adjacent sections of RLn+1 and RLn-1. In this case, the values ldsh and ldshk can have maximum values [6; 10].

4. The shunt mode of operation of the RLn track circuit will also depend on the presence of shunts both on the RLn and on a part of adjacent rail lines. The shunting zone *l*sh =*l*dshk +*l*kn+*l*dshn is called the train length of the track circuit. When the train is on an adjacent track circuit, a complex shunt Zsh =Rsht + z**l*dshk or Zsh =Rsht + z**l*dshk is connected to the equipment connection points. In order for the train not to block the traffic light itself when approaching the track circuit, the traffic light must be installed in the direction of the train at a distance *l*dshk [7; 13].

2. Methodology and empirical analysis

Coefficients of a rail quadripole of an intelligent sensor

Fig. 3 shows the developed structural of the intelligent track control sensor. To study this track circuit, transformations were carried out

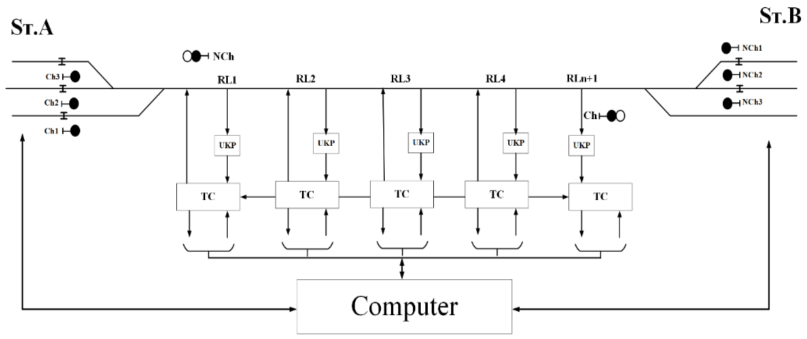

Fig. 3. Structural scheme of an intelligent track control sensor

In the analysis and synthesis of intelligent sensors, the main equations are given that allow taking into account the features associated with the absence of insulating joints.

The coefficients of the four-terminal jointless track circuit in the intelligent sensor can be determined from the equivalent circuit of the jointless track circuit in Fig. 2. under initial conditions different from those adopted for track circuits with insulating joints [7; 9].

Let us replace adjacent track threads on the right and left sides with input resistances Zin and Zin, then the general equivalent circuit can be represented as the circuit shown in Fig. 4.

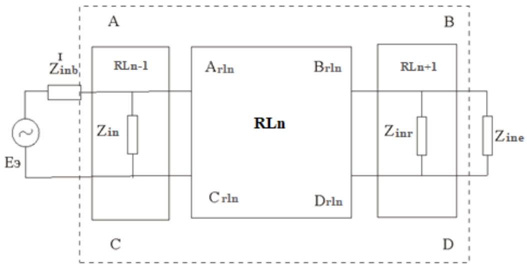

Fig. 4. Substitution scheme for track control sensor

Where:

A, B, C, D are coefficients quadripole

Z_{in} is resistance of the beginning of influence on the sensor

Z_{ine} is end resistance of the influence on the sensor

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Z_{inr} is resistance of the beginning of the adjacent rail line of influence on the sensor

RL_{n-1}, RL_{n+1} are quadripoles of adjacent rail lines

Z^{I}_{inb} is incoming resistance of the beginning of rail lines

Z^{I}_{ine} is incoming resistance of the end of rail lines

The rail quadripole coefficients for the jointless rail circuit A, B, C and D are obtained by multiplying the matrices:

$$\begin{Vmatrix} A & B \\ C & D \end{Vmatrix} = \begin{Vmatrix} A_{rln-1} & B_{rln-1} \\ C_{rln-1} & D_{rln-1} \end{Vmatrix} * \begin{Vmatrix} A_{rln} & B_{rln} \\ C_{rln} & D_{rln} \end{Vmatrix} * \begin{Vmatrix} A_{rn+1} & B_{rln+1} \\ C_{prln+1} & D_{rln+1} \end{Vmatrix} \qquad (1)$$

After multiplying the matrices, we get:

$$A = cos\gamma l + \frac{z_w}{Z_{inp}} sin\gamma l;$$
$$B = z_w * sh\gamma l;$$
$$C = \frac{sin\gamma l}{z_w} + \frac{cos\gamma l}{Z_{inri}} + \frac{z_w sin\gamma l}{Z_{inr} * Z_{inri}} + \frac{cos\gamma l}{Z_{inr}};$$
$$D = \frac{z_w}{Z_{inri}} cos\gamma l + \frac{z_w}{Z_{inri}} sin\gamma l: \qquad (2)$$

For a number of special cases, the calculation equations for the coefficients of a rail quadripole are greatly simplified and take on a form convenient for practical calculations:

$$A = cos\gamma l + \frac{z_в}{Z_{wri} tan\gamma_r l_{shr}} sin\gamma l;$$
$$B = z_w * sin\gamma l;$$
$$C = \frac{z_в sin\gamma l}{Z_{wri} tan\gamma_{ri} l_{sinri} * Z_{shr} tan\gamma_r l_{sinr}} + \frac{cos\gamma l}{Z_{wr} tan\gamma_r l_{sinr}};$$
$$D = cos\gamma l + \frac{z_в}{Z_{wri} tan\gamma_{ri} l_{sinri}} sin\gamma l. \qquad (3)$$

if there are insulating joints and choke-transformers at the supply end of the rail circuit, zvp = ∞.

$$A = cos\gamma l + \frac{Z_в}{Z_{wr} ctan\gamma_r l_{shr}} sin\gamma l;$$
$$B = Z_{wri} sin\gamma l;$$
$$C = \frac{1}{Z_w} sin\gamma l + \frac{cos\gamma l}{Z_{wr} tan\gamma_r l_{sinr}};$$
$$D = cos\gamma l + \frac{sin\gamma l}{Z_{wr} tan\gamma_r l_{sinr}}; \qquad (4)$$

if there are insulating joints and choke-transformers at the relay end of the rail circuit, zvr=∞.

$$A = cos\gamma l + \frac{sin\gamma l}{Z_{wr} tan\gamma_r l_{sinr}};$$
$$B = Z_{wr} cos\gamma_r;$$
$$C = \frac{1}{Z_w}\left(sin\gamma l + \frac{cos\gamma l}{Z_{wri} tan\gamma_{ri} l_{sinri}}\right);$$
$$D = cos\gamma l + \frac{Z_в}{Z_{wri} tan\gamma_{ri} l_{sinri}} sin\gamma l. \qquad (5)$$

when one moving unit is located on an adjacent rail line at the relay end:

$$A = cos\gamma l + \frac{z_в}{Z_{wr} ctan\gamma_r l_{shr}} sin\gamma l;$$
$$B = z_w * sin\gamma l;$$
$$C = \frac{sin\gamma l}{z_w} + \frac{cos\gamma l}{Z_{wri}} + \frac{z_в sin\gamma l}{Z_{wri} th\gamma_r l_{sinr} * Z_{wri}} + \frac{cos\gamma l}{Z_{wr} tan\gamma_r l_{shr}};$$
$$D = cos\gamma l + \frac{Z_w}{Z_{wri}} sin\gamma l. \qquad (6)$$

on an adjacent rail line at the supply end:

$$A = cos\gamma l + \frac{Z_w}{Z_{wr}} sin\gamma l;$$
$$B = z_w * sin\gamma l;$$
$$C = \frac{sin\gamma l}{z_w} + \frac{cos\gamma l}{Z_{wri} tan\gamma_{ri} l_{shri}} + \frac{z_в sin\gamma l}{Z_{wri} tan\gamma п_r l_{sinri} * Z_{wr}};$$
$$D = \frac{z_в}{Z_{wr} tan\gamma_r l_{sinr}} + sin\gamma l. \qquad (7)$$

Thus, by substituting in these expressions, the values of the obtained equations for the coefficients of the rail quadripole, it is possible to calculate the values of voltages and currents when the insulation resistance of all rail lines changes in any combination, thereby conducting studies of seamless track circuits in all operating modes.

3. Results and Discussion

At present, voice frequency sensors, toneless jointless track circuits are used on railways, due to the lack of joints, the supply voltage to the rail line also affects neighboring rail lines, and the increased frequency has the property of attenuation, which reduces the length. The aim of the study is to increase the length and reduce the energy consumption of voice frequency rail circuits at the same energy costs. To do this, on the developed simulation model, develop a mathematical model for the presented new microprocessor automatic blocking scheme using the proposed intelligent sensor.

As studies show, as a result of the development of a mathematical model, it is clearly shown that the transition from a relay receiver to an intelligent sensor, a microprocessor-based basis for receiving information along a rail line, reliably performs operating modes in the normal and shunt modes of operation of track circuits, and also when the ballast changes, it reliably fixes the train on plot.

All calculations of the adaptive sensor were carried out in two forms: calculations in the analysis and calculations in the synthesis of jointless tone track circuits. The task of the analysis is to determine the influence of various elements of the sensor on the performance of a particular mode of operation. During the synthesis, the optimal parameters of the elements were chosen, which ensure the functioning of adaptive sensors for operating modes in adverse conditions.

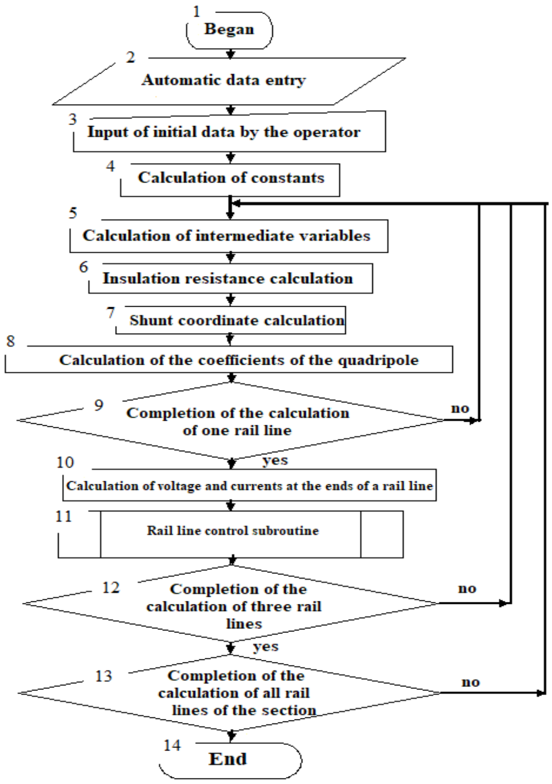

Fig. 5. Blok-scheme algorithm work a sensors

Taking into account the above-given and transformed electrical circuits of the intelligent control sensor, a mathematical model of the controlled section was compiled. The algorithm of this model is presented in Fig. 5. In accordance with the algorithm, a program was developed, which is an integral part of the programs for the study of adaptive sensors.

Below is the developed algorithm for track circuits located on the section of the haul.

The proposed scheme of an intelligent control sensor shows that when the insulation resistance changes along the entire length of the section, the voltage and current are clearly fixed by the microprocessor circuit, where this can be seen in fig. 6

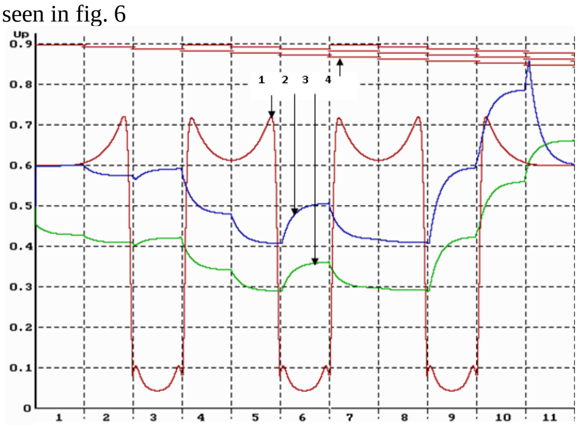

Fig. 6. Change in insulation resistance along the entire length of the section

Thus, we see that the intelligent sensor detects the presence of a moving unit when the insulation resistance changes, thus, while consuming less electricity, it is possible to increase the length of the sensor with microprocessor technology and clearly indicate the presence of a moving unit on the track.

The conducted studies correspond to one of the most important points of railway automation and telemechanic namely the safety of railway transport, the study shows that a system with an intelligent sensor also leads to energy savings and other disturbing factors affecting the track and track facilities.

4. Conclusion

A technique is given for the exact determination of the coefficients of a rail quadrupole of intelligent sensors for asymmetric rail lines with different values of the primary and secondary parameters of adjacent rail lines. Equations for a rail quadripole of intelligent sensors for asymmetric rail lines are obtained.

Thus, the presented intelligent sensor based on seamless intelligent track circuits can be continued to study the operation of train location and rail break detection systems, obtain more reliable information, and therefore ensure greater safety during transportation.

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