Monitoring of Quality of Code Current in Rail Circuits

Tatyana Serdyuk*, Vladimir Gavrilyuk

Chair of Automatics and telecommunication, Dniepropetrovsk national university of railway transport named acad. Lazaryana, Acad. Lazaryana street 2, 49010 Dniepropetrovsk, Ukraine

*Corresponding Author: serducheck_t@fromru.com

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Abstract This paper deals with the elaboration of the method of definition of primary and secondary parameters of the rail circuits on the base of the measuring car-laboratory with the help of special program microprocessor apparatuses. It was proposed advanced mathematic model of the information channels (rail circuits) for scientific substantiation of a method of the code parameters measurement. The measurement of current in the rail circuit is carried out in the regime of automatic locomotive signaling. The parameters of the rail circuits are defined by the value of code current of the rail circuits in the beginning and the end of the rail path. The results of modeling are presented for the 50 Hz code rail circuit.

Keywords Code Current, Measurement, Car-laboratory, Rail Circuit

1. Introduction

It is known fact that the principle of work of automatic locomotive signaling system is based on the transferring signal current by frequency 50 Hz (at the d. c. traction) and 25 or 75 Hz (at the a. c. traction) from the rail circuit to the locomotive receiving coils. The code current is formed by impulses and pauses. This code corresponds to indications of traffic lights. So, the “Green code” has three impulses and three pauses, the “Yellow code” has two impulses and two pauses, the “Red-yellow code” has one code and one pause. The last pause is longer than the first one and it is named as a dividing pause in all kinds of codes.

All control methods of technical service of rail circuits are possible to be divided in two kinds. The first method deals with the going out on a railway section and carrying out measurement of resistance of a rail circuit, the resistance of the ballast isolation, the voltage and current in the beginning and the end of a rail circuits. The second method allows us to determine the time and numerical parameters of a code current in rails during measuring trip of a car - laboratory. So the primary and the secondary parameters of a rail circuit are not defined in this case.

Serviceability of a railway automatics device is depended from a quality of measurements and appliance of progress method of service. Existing methods of service of rail circuits are based on the physically and morally obsolete apparatuses means, which are not ensured accuracy requirements.

It is possible to distinguish the following deficiencies in the existing methods of control of rail circuits. These are a little number of controlled parameters, the difficulty and subjectivity of evaluation of measurement data.

The modern microprocessor systems allow us to remove the above mentioned deficiencies, to increase the number of checked parameters and measurement accuracy, to control the deviation from norms, to record and save information in the digital form to magnetic or optical carriers.

The main idea of this work is elaboration of method to determine primary and secondary parameters of rail circuits by the measurements with the help of car-laboratory and special microprocessor system for the control of parameters of code current in rails [1, 2].

2. Mathematical Model

It is known, that the principle of work of automatic locomotive signaling (ALS) and automatic block systems is based on the transfer of the codes to the locomotive or receiving apparatuses of rail circuit. It is used 50 Hz frequency of code current in the d. c. electrical traction, and 25 and 75 Hz – in the a. c. electrical traction [3].

The equipment of a car-laboratory is used for definition parameters of the code current in rails during measurement travel usually two times in a year. The experimental data can be obtained with help of a special elaborated measuring system [1, 2], based in the car-laboratory for controlling the parameters of the code current. So there is a continuous communication between track and locomotive devices in the system of the automatic locomotive signaling system. The coils are situated before the first wheel pair of a locomotive and it is connected inductively with the current in rails by means of the magnetic field, series and towards each other. The magnetic field is formed around rails by the alternating code current. Thus, there is a separate channel of communication within the limits of each rail circuit.

For determination of parameters of a rail circuit we used the equivalent scheme, given in figure 1.
This scheme includes the supplying end, the rail lines and the receiving end, each from which are the 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.

The measurement of current of rail circuit is carried out in the beginning and the end in the regime of automatic locomotive signaling. This regime is characterized by the following conditions for the serviceable and occupied rail circuits: the level of the code current has to be sufficient to the reliable switching of a relay of a locomotive, situated on the more removed end from the generator of the code current. The parameters of rail circuits are specified in this regime as follow: the specific resistance of rails is maximal; the specific conductivity of isolation of rails is maximal; the voltage of source is minimal.

The criteria of the reliable automatic locomotive signaling regime is as follow: the factual minimal current in rails should not be less than a normative current (which is equal 1.2 A at the autonomy traction, 1.4 A at the a. c. electrical traction, 2 A at the d. c. electrical traction) at the putting of train shunt on the more removed end from a code generator [4, 5]. The equivalent scheme of rail circuits is shown in figure 2 at the present train shunt on the receiving end (in the regime of automatic locomotive signaling).

According with the theory of four-poles let us write the system of equation of voltage and current in the beginning of a rail circuit:

\[
\begin{align*}
U_s &= A_{sh} \cdot U_r + B_{sh} \cdot I_r, \\
I_s &= C_{sh} \cdot U_r + D_{sh} \cdot I_r,
\end{align*}
\]  

(1)

where \(U_s\), \(I_s\) are the voltage and the current at the beginning of rail circuits (supplying end), \(U_r\), \(I_r\) are the voltage and the current at the end of rail circuits (at the point of putting a train shunt), \(A_{sh}, B_{sh}, C_{sh}, D_{sh}\) are the coefficients of rails four-poles in the regime of automatic locomotive signaling.

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

\[
A_{sh} = 1 + \frac{Z}{R_{sh}}, \quad B_{sh} = Z, \quad C_{sh} = \frac{1}{R_{sh}}, \quad D_{sh} = 1,
\]

(2)

where \(Z = z \cdot l\) is the resistance of the rail line, Ohm, \(Z\) is the specific resistance of the rail lines, Ohm/km, \(l\) is the distance between the supplying end and locomotive, km, \(R_{sh}\) is the resistance of the train shunt, \(R_{sh} = 0.06\) Ohm.

Carrying out some mathematical transformations, taking into account that the voltage at the more removed end of the rail circuit from generator is \(U_r = I_r \cdot R_{sh}\) we can get:

\[
\begin{align*}
U_s &= \left(1 + \frac{Z}{R_{sh}}\right) \cdot I_r \cdot R_{sh} + Z \cdot I_r, \\
I_s &= \frac{1}{R_{sh}} \cdot I_r \cdot R_{sh} + I_r, \\
U_s &= \left(R_{sh} + Z\right) \cdot I_r + Z \cdot I_r, \\
I_s &= 2 I_r.
\end{align*}
\]

(3)

So, knowing the value of a current in the beginning and the end of a rail circuit and the voltage at the output of a code generator, which should be equal to the minimal voltage of a track transformer \(U_s = U_{\text{min}}\) and it can be taken from the regulative tables [4], we can define the resistance of rail lines:
\[
\tilde{Z} = \frac{U_{\min} - I_r \cdot R_{sh}}{2 \cdot I_r},
\]

(4)

Let’s determine the secondary parameters of rail circuits, the propagation coefficient and the wave resistance. It is known that the coefficients of rail four-poles are defined with the help of the secondary parameters of rail circuits [3]:

\[
A = D = ch(\gamma l), \quad B = Z_v \cdot sh(\gamma l), \quad C = \frac{sh(\gamma l)}{\tilde{Z}_v},
\]

(5)

where \(\tilde{Z}_v\) is the wave resistance of a rail line, Ohm, \(\gamma\) is the propagation coefficient of a wave, 1/km, \(l\) is the length of a rail circuits, km.

We will have at the putting of train shunt on the receiving end: \(A = A_{sh}\), \(B = B_{sh}\), \(C = C_{sh}\), \(D = D_{sh}\).

Then

\[
\tilde{Z} = \tilde{Z}_v \cdot sh(\gamma l), \quad \tilde{Z}_v = \frac{\tilde{Z}}{sh(\gamma l)}, \quad \frac{1}{R_{sh}} = \frac{sh(\gamma l)}{\tilde{Z}_v},
\]

(6)

The wave resistance of rail lines and the propagation coefficient are equal

\[
\tilde{Z}_v = \sqrt{\tilde{Z} \cdot R_{sh}},
\]

(7)

\[
\gamma = \text{arcsinh} \left( \frac{\tilde{Z}_v}{\sqrt{\tilde{Z}}} \right),
\]

(8)

The wave resistance is connected with the primary parameters of rail circuits as follows [3]

\[
\tilde{Z}_v = \sqrt{\tilde{z} \cdot R_{is}},
\]

(9)

where \(R_{is}\) is the equivalent resistance of isolation of a rail line and grounding of supports of catenary, Ohm km.

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

\[
R_{is} = \frac{\tilde{Z}_v^2}{\tilde{Z}}.
\]

(10)

So, knowing the value of current in the beginning and the end of rail circuits in the results of measurements with the help of equipment, installed on the car-laboratory, and taking the value of generator’s voltage from regulation tables we can define the primary (a resistance of rail lines and resistance of isolation) and the secondary (a wave resistance and a wave propagation coefficient) parameters of rail circuits.

3. Result of Modeling

Let’s consider the question of determination of the primary and the secondary parameters of a code rail circuit with two choker-transformers. Carrying out the calculations we will suppose that the rail lines are homogenous. It is necessary to know the value of minimal voltage of supplying end, which is depended from the length of the rail circuits, the resistance of train shunt \(R_{sh} = 0.06\) Ohm, the amplitude of current in the beginning and the end of lines for the calculation.

The rail circuit will work in the regime of automatic locomotive signaling at the putting of train shunt at the receiving end. This regime is characterized by the increase of current in rails when approaching a train to the supplying end. This dependence has an exponential character

\[
I(x) = I_s \cdot e^{-\gamma \cdot x},
\]

where \(x\) is the distance between the supplying end and the train (figure 3). All the following results are given for the case, when the length of a rail circuit is equal \(l = 2600\) m, the current in the beginning of the rail circuit is \(I_s = 10\) A, and it is equal at the end \(I_r = 4\) A, the minimal voltage of the supplying end is \(U_{\min} = 152\) V.

The dependence of the resistance of the rail circuit from the coordinate is calculated by the formula (4) and it is shown in figure 4. Given results are overestimated a little in the comparison with the directory data, because it takes into account input resistance of apparatuses of the supplying end. So we adopt \(Z(0) \neq 0\) at the point \(x = 0\) for the same reason. As a whole dependence \(Z(x)\) has a nonlinear character and it reduces when approaching to the source.

The dependence of conductivity of isolation from the distance between the supplying end and the locomotive is represented in figure 5. The conductivity of isolation increases with decrease of the distance (coordinate \(x\)).

The dependence of conductivity of isolation from the distance between locomotive and supplying end was defined by:

\[
\gamma_{is} = \frac{\gamma(l)^2}{z \cdot l}.
\]

The input resistance of rail circuit calculated by the expression \(Z_{in}(l) = \sqrt{Z(l) \cdot R_{sh}}\) is shown in figure 6. The input resistance of the rail circuit reduces when approaching of a train to the supplying end.

The dependence of the propagation coefficient in the rail line from the distance between source \(\gamma(\delta)\) and train shunt is given in figure 6 and it is calculated by the formula (8). The coefficient \(\gamma\) decreases with increase of coordinate \(x\).

The wave resistance \(Z_v\) does not depend from the coordinate, because it is necessary only the specific
resistance of line and isolation resistance for its determination. That is why it is calculated very easy by the results of indirect measurements (9).

![Figure 3](image3.png) Dependence of current in rails from the distance between locomotive and supplying end of given rail circuit

![Figure 4](image4.png) Dependence of conductivity of isolation from the distance between locomotive and supplying end

![Figure 5](image5.png) The dependence of input resistance of rail circuit from the distance between locomotive and supplying end

![Figure 6](image6.png) The dependence of wave propagation coefficient from the distance between locomotive and supplying end

4. Conclusion

This paper deals with the questions of improvement of technological service of rail circuits by the automation of control of its parameters with the help of the developed method of the automated measurement of parameters of rail circuits, current of automatic locomotive signaling system in rail lines.

The mathematical model of electromagnetic processes in the system “rails – receiving coils of automatic locomotive signaling system” was elaborated. It is given scientific base to the method of automated check of parameters of rail circuits with the help of a car-laboratory and to increase the measurements accuracy.

The method for the definition of primary and secondary parameters of rail circuits is elaborated based on results of measurements with the help of equipment of car-laboratory. This method is allowed us to determine parameters of rail circuits by the measured current in the beginning and the end of a rail circuit. It considerably reduces the expenses on the service of rail circuits and improves the service quality. The results of calculation of resistance of rail circuit, conductivity of isolation, input resistance and propagation coefficient are given in the dependence from the distance between locomotive and supplying end for the code rail circuit of 50 Hz with the two choker-transformers by the maximal length of 2.6 km.

The technical realization of the method of automated measurement of rail circuits parameters and, in particular, parameters of code current of automatic locomotive signaling system were carried out in view of apparatuses-program complex and realized on the base of a car-laboratory [6].

The proposed method is advanced in comparison with existing methods because of using new program-apparatuses, where calculation is done on the base of elaborated mathematic models, and can be recommended for the application on a railway of Ukraine in opinion of the authors.

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