METHODS FOR CALCULATING THE COEFFICIENTS OF THE RAIL FOURPOLE OF SENSORS CONTROL TONAL FREQUENCY

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METHODS FOR CALCULATING THE COEFFICIENTS OF THE RAIL FOURPOLE OF SENSORS CONTROL TONAL FREQUENCY

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Abstract: For develop sensors of controlling the state of track sections in interval train control systems, it is first necessary to determine the coefficients of the fourpoles of the rail lines, taking into account the influence of adjacent rail lines and the availability of trains on these lines. The article reviewed methods for determining these coefficients, which are in the further at of researches and development of such sensors will allow of the creation of modern sensors controlling, ensuring the safety of train traffic.

Keywords: control sensors, tonal rail chains, train shunts, adjacent sections, wave impedance, wave propagation constant, coefficients of fourpoles

Introduction

Due to the fact that the operating principles of sensors control without insulating joints differ from typical rail chains, then models and calculation methods of typical rail lines cannot be used for the development and research of sensors control without insulating joints [1, 2], as in typical rail chains with insulating joints there is no need to account for two trains on a rail chain, the presence of trains on adjacent rail chains, dynamics of insulation resistance [5], longitudinal asymmetry of insulation resistance. For the development of sensors control without insulating joints requires the development of new methods and models of rail lines [4, 7], which must take into account the above factors.

Main part

For the analysis and synthesis of such sensors, it is necessary to determine the coefficients of rail fourpole [4, 6, 9-12].

Figure 1. The substitutions scheme of the sensor controls tonal frequency without isolating joints, taking into account the influence of adjacent rail lines.
Sensor control the condition of the track sections of the tonal frequency without insulating joints length \( L = l_2 + l_3 \) with superimposed shunts \( R_{sh1}, R_{sh4}, R_{sh2}, R_{sh3} \), located at a distance \( l_1, l_4, x_2, x_3 \) respectively, can be represented as an substitution scheme in Fig. 1, consisting of a cascade connection of six fourpoles \( RL_1, RL_{II}, RL_2, RL_{II}, RL_3, RL_4 \).

In this scheme, we replace adjacent rail lines with superimposed shunts \( R_{shi1}, R_{she4} \), input impedances \( Zin_3, Zin_4 \), then the scheme of Fig. 1 transformed to the scheme of Fig. 2.

![Figure 2. The substitutions scheme sensor controls tonal frequency without isolating joints with connect the input impedances of adjacent rail lines.](image1)

where

\[
Z_{in1} = \frac{ch_y l_1 + R_{sh1} + Z_{w1} s_h y l_1}{Z_{w1} s_h y l_1 + R_{sh1} + ch_y l_1}
\]

\[
Z_{in4} = \frac{ch_y l_4 + R_{sh4} + Z_{w4} s_h y l_4}{Z_{w4} s_h y l_4 + R_{sh4} + ch_y l_4}
\]

So that simplify the circuit in Fig. 2, we replace the section \( l_1 \) with the input resistance

\[
Z_{in1} = \frac{A_2 + Z_{le} + B_2}{C_2 + Z_{le} + D_2}
\]

![Figure 3. The substitutions scheme of the rail line with the left side from of the power source.](image2)

The coefficients of the fourpole \( RL_2 \) are determined through cascade-connected fourpoles \( Z_{a1}, RL_1, RL_{II}, R_{sh2} \)

\[
\begin{vmatrix}
A_2 & B_2 \\
C_2 & D_2
\end{vmatrix} = \begin{vmatrix}
A_1' & B_1' \\
C_1' & D_1'
\end{vmatrix} \begin{vmatrix}
\frac{1}{1} & 0 \\
1 & 1
\end{vmatrix} \begin{vmatrix}
A_1'' & B_1'' \\
C_1'' & D_1''
\end{vmatrix} \begin{vmatrix}
\frac{1}{Z_{le}} & 0 \\
1 & 1
\end{vmatrix}
\]
The scheme also consists of a cascade connection of five fourpole $Z_{\text{in1}}, RL_1^I, R_{sh3}, RL_1^H, Z_{id4}$

$$\begin{vmatrix}
A & B \\
C & D
\end{vmatrix} = \begin{vmatrix}
1 & 0 \\
1 & 1
\end{vmatrix} \begin{vmatrix}
A_3^I & B_3^I \\
C_3^I & D_3^I
\end{vmatrix} = \begin{vmatrix}
1 & 0 \\
1 & 1
\end{vmatrix} \begin{vmatrix}
A_3^H & B_3^H \\
C_3^H & D_3^H
\end{vmatrix} = \begin{vmatrix}
1 & 0 \\
1 & 1
\end{vmatrix} \begin{vmatrix}
A_4^I & B_4^I \\
C_4^I & D_4^I
\end{vmatrix}$$

This scheme also consists of a cascade connection of five fourpole $Z_{\text{in1}}, RL_1^I, R_{sh3}, RL_1^H, Z_{id4}$

Figure 4. Generalized scheme of the sensor control tonal frequency without isolating joints.
After matrix multiplication and coefficient substitution \( A_3^1, B_3^1, C_3^1, D_3^1, A_3^II, B_3^II, C_3^II \) and \( D_3^II \), we get

\[
A = \left( ch_3 (l_3 - x_3) + \frac{Z_{w_3} * sh_3 (l_3 - x_3)}{R_{sh_3}} \right) \left( ch_3 x_3 + \frac{Z_{w_3} * sh_3 (l_3 - x_3)}{Z_{i_4}} \right) + Z_{w_3} sh_3 (l_3 - x_3) \left( \frac{1}{Z_{w_3}} * sh_3 x_3 + \frac{ch_3 x_3}{Z_{i_4}} \right);
\]

\[
B = Z_{w_3} * sh_3 x_3 \left( ch_3 (l_3 - x_3) + \frac{Z_{w_3} * sh_3 (l_3 - x_3)}{R_{sh_3}} \right) + Z_{w_3} sh_3 (l_3 - x_3) ch_3 x_3;
\]

\[
C = \left( \frac{1}{Z_{w_3}} * sh_3 (l_3 - x_3) + \frac{ch_3 (l_3 - x_3)}{Z_{i_4}} \right) \left( \frac{1}{Z_{w_3}} * sh_3 x_3 + \frac{ch_3 x_3}{Z_{i_4}} \right) \left( \frac{1}{Z_{w_3}} * sh_3 x_3 + \frac{ch_3 x_3}{Z_{i_4}} \right) * ch_3 (l_3 - x_3) + \frac{Z_{w_3} * sh_3 x_3}{Z_{i_4}} \right) + \frac{Z_{w_3} * sh_3 (l_3 - x_3)}{Z_{i_4}} + ch_3 (l_3 - x_3) * \left( \frac{1}{Z_{w_3}} * sh_3 x_3 + \frac{ch_3 x_3}{Z_{i_4}} \right);
\]

\[
D = Z_{w_3} * sh_3 x_3 \left( \frac{1}{Z_{w_3}} * sh_3 (l_3 - x_3) + \frac{ch_3 (l_3 - x_3)}{Z_{i_4}} \right) \left( \frac{1}{Z_{w_3}} * sh_3 x_3 + \frac{ch_3 x_3}{Z_{i_4}} \right) * \left( l_3 - x_3 \right) \frac{Z_{w_3} * sh_3 (l_3 - x_3)}{Z_{i_4}} + ch_3 (l_3 - x_3)
\]


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