Determination of the optimal parameters of the control sensor at the crossing in the control mode

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Abstract. On railway sections where there are intersections with road transport, control systems for crossing signaling with auto barriers are arranged. To control the entrance of the train to this section, track circuits with insulating joints are used. Such circuits have a number of significant drawbacks, one of which is the coming off of insulating joints, as well as breakage of the track circuit, which give 45% of the failures of automation systems on the haul. In this article, a study was made of a crossing track circuit with a tone frequency for the control mode. For the study, mathematical expressions for determining the most unfavorable moment were derived, an algorithmic expression for the control mode coefficient was presented, which gives more accurate information about the presence of damage. As a result, a block diagram was developed and graphs were displayed on the simulation model showing the influence and determination of the control mode of operation of the jointless tone track circuit. In conclusion, the results of the study are summarized. **Key word**. rail circuit, jointless tone track circuit, railway sections, automation systems, control mode, coefficient

1 Introduction

To prevent breakage and descent of the insulating joint, they began to use track circuits without insulating joints with potential receivers [1-3], but they also have disadvantages, expressed in the fact that when a train approaches such circuits, the train begins to shunt the track circuit at a certain distance from the border of the track circuit [4-11], and also continues to shunt the track circuit when leaving, i.e. there are additional shunting zones for the approach and departure of the train from the track circuit. This zone can vary widely depending on state of upper structure of the track [12-20].

To eliminate this shortcoming, it is proposed to use a jointless tone rail circuit with current receivers [2, 3]. Due to the fact that such circuits have not been fully investigated, the article proposes a method for determining the main parameters of a tonal jointless rail circuit with current receivers in one of the circuit operation modes [21-23].

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2 Main part. Methodology for deriving analytical expressions for researching a track circuit in the event of a break in one of the threads

Currently, the world's railway network began to introduce tonal track circuits in the frequency range of 420-480 Hz with potential receivers [6, 9]. One of the tonal circuit options is a tonal jointless track circuit with current receivers Fig. 1

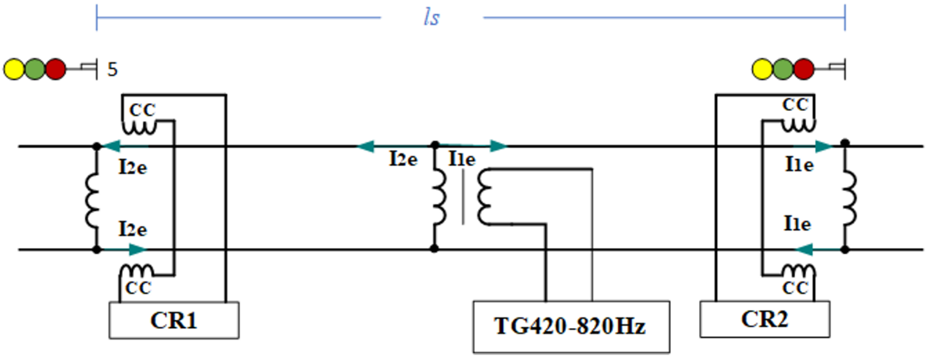

Fig. 1. Tonal jointless track circuit with current receivers

Rail circuits operate in three main modes are normal, shunt and control. In the control mode, a break in one of the threads of the rail loop is checked. When one of the threads of the rail loop breaks, a complete break does not occur due to current leakage through the ballast along the rail-ballast, rail-rail line, as shown in Fig. 2.

In the general case, a rail line is considered in the form of two rail-ground circuits connected by mutual inductance M12 and the corresponding mutual inductance resistivity zm = j2πfM12. Conductivities q1 and q2 characterize the transient conductivities between each rail and the ground, respectively, to the right and left of the connection points of the track circuit equipment, conductivities q12 characterize the part of the leakage current passing directly from rail to rail along the upper ballast layer and sleepers. Zm is the resistivity of the mutual inductance of the rails, and for the convenience of calculations, we replace the right side of the approach section from the track generator with its input resistance Zin2, then the equivalent circuit of the rail circuit will look like Fig.2.

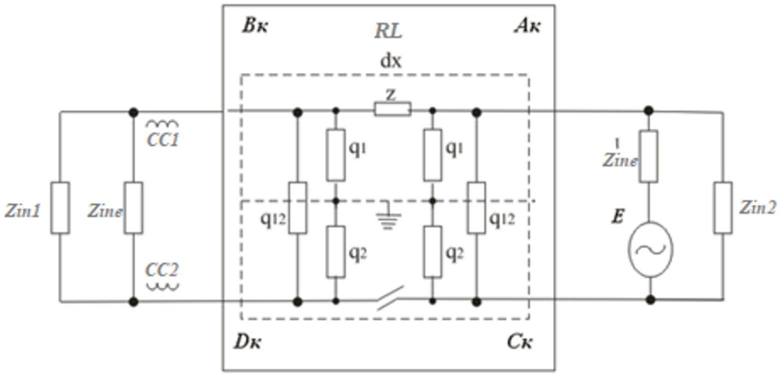

Fig. 2. Equivalent circuit of the rail circuit of the approach section in case of a break in one of the rail threads

The rail quadripole coefficients for this circuit can be represented as the following equations:

$$A_k = ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21} + E\sqrt{1+2p}(ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21}) + E\sqrt{1+2p}; \tag{1}$$

$$B_k = \frac{zl}{\gamma_{21}l_{21}}\left[sh\gamma_{21}l_{21} + E\sqrt{1+2p}(ch\gamma_{21}l_{21} + 1)\right]; \tag{2}$$

$$C_k = \frac{2\gamma_{21}l_{21}}{zl}\left[1 + E\sqrt{1+2p}\right]\left[ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21}\right]; \tag{3}$$

$$D_k = ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21} + E\sqrt{1+2p}(ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21}) + E\sqrt{1+2p}. \tag{4}$$

The rail break sensitivity quantifies the effect of current reduction in the track receiver in the control mode:

$$K_k = \frac{I_{bb}}{I_{fmax}}. \tag{5}$$

$$I_{bb} = I_{mid} * k_r = \frac{U_{min} * k_r}{Z_{tr}}; \tag{6}$$

where Umin is the minimum voltage of the power supply;
Кr is coefficient of reliable return of the track receiver;
Ztr is transmission resistance of the track circuit in normal operation

$$Z_{tr} = A_0 * \frac{Z_{ine} * Z_{v1}}{Z_{ine} + Z_{v1}} + B_0 + \frac{A_o}{Z_{vx22}} + Z^{I}_{inb}\left(C_0 * \frac{Z_{ine} * Z_{v1}}{Z_{ine} + Z_{v1}} + D_0 + \frac{C_o}{Z_{vx22}}\right).$$

$$I_{fmax} = \frac{U_{max} * k_v}{Z_{te}}. \tag{7}$$

Where U_{max} is the maximum voltage of the track circuit power supply;
k_v is coefficient of reliable return of the track receiver;
Z_{te} is rail circuit transmission resistance when one of the threads of the rail loop breaks (control mode of operation):

$$Z_{te} = A_{\text{К}} * \frac{Z_{ine} * Z_{v1}}{Z_{ine} + Z_{v1}} + B_{\text{К}} + \frac{A_k}{Z_{vx22}} + Z^{I}_{inb}\left(C_{\text{К}} * \frac{Z_{ine} * Z_{v1}}{Z_{ine} + Z_{v1}} + D_{\text{К}} + \frac{C_k}{Z_{vx22}}\right).$$

Substituting equations (6 and 7) into equation (5) we get:

$$K_k = \frac{\frac{U_{min} * k_r}{Z_{tk}}}{\frac{U_{max} * k_r}{Z_{tk}}} = \frac{U_{min} * k_r * Z_{re}}{U_{max} * k_z * Z_{tr}}.$$

Let's replace

$$\frac{U_{min} * k_r}{U_{\text{мах}} * k_z} = \frac{1}{N},$$

where N is a hardware coefficient equal to 1.7, then

$$K_k = \frac{A_{\text{К}} * \frac{Z_{ine} * Z_{v1}}{Z_{ine} + Z_{v1}} + B_{\text{К}} + Z^{I}_{inb}\left(C_{\text{К}} * \frac{Z_{ine} * Z_{v1}}{Z_{ine} + Z_{v1}} + D_{\text{К}}\right)}{N * A_0 * \frac{Z_{ine} * Z_{v1}}{Z_{ine} + Z_{v1}} + B_0 + Z^{I}_{inb}\left(C_0 * \frac{Z_{ine} * Z_{v1}}{Z_{ine} + Z_{v1}} + D_0\right)} \tag{8}$$

This equation is the main one for determining the optimal parameters of the track circuit when one of the threads of the track loop breaks (control mode).

3 Result and discussion. Algorithm for determining the optimal parameters of a seamless track circuit with current receivers

On the basis of equation (8), an algorithm for conducting studies of the track circuit in the control mode was compiled.

The search for the optimal resistance at the ends of the track circuit from the condition of ensuring control of the rail break is carried out in two stages: at the first stage, the minimum value of the transmission resistance Ztrmin is determined, at the second stage, the optimal resistance at the ends of the track circuit is calculated, at which control of the break of the rail loop will be ensured according to the following algorithm fig.3.

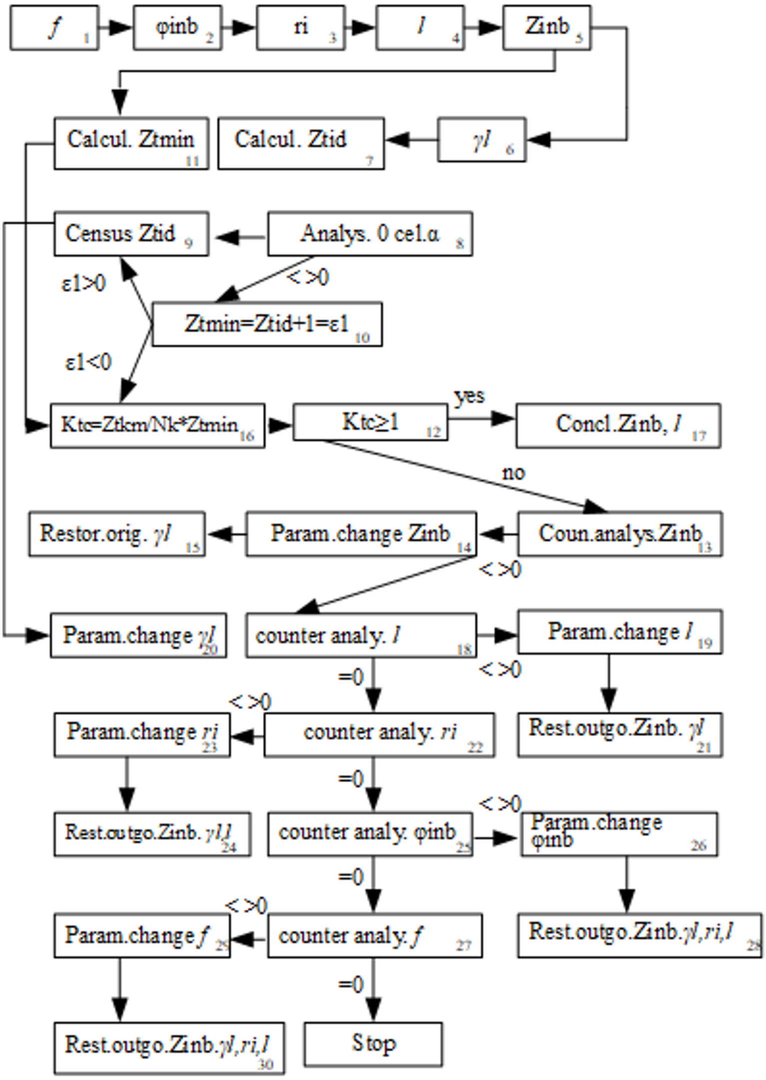

Fig.3. Block diagram of the algorithm for determining the optimal parameters of the control sensor from the condition of ensuring normal and control modes of operation

When determining the optimal resistance modulus, the following initial data are entered: signal current frequencies f, modulus and argument of resistances at the ends of the track circuit, all possible values of l and γl.

In the process of searching for the optimal value, operators 1÷6 form contacts and send them to the cycle counters to organize finding the minimum of the function $Z_{\text{trmin}} = f(|\gamma l|)$ and the optimal value of the resistance modulus for various options.

After determining the minimum value of the function $Z_{\text{trmin}} = f(|\gamma l|)$, control is transferred to operators 16 and 12, who calculate the criterion of sensitivity to a broken rail line and compare this criterion to control a broken rail line $K_{cb} \geq 1$.

If the sensitivity criterion is less than one, then control is transferred to operators 13÷15, which change the contents of the cycle counter by the Z_{inb} parameter by one, change the Z_{inb} parameter by the value of its step and restore the value of γl. If the sensitivity criterion is equal to or greater than one, then the control is transferred to the operator 17, which prints out the Z_{inbopt} values and transfers the control to 18 ÷ 30, which are a block diagram of the options. Each of them changes the contents of the loop counter for a specific parameter by one, analyzes it to zero, and, if the contents of the loop counter is not equal to zero, changes this parameter by the value of its step and transfers control to restore the initial data of subsequent parameters. If the contents of the counters turn out to be equal to zero, then control is transferred to the operators organizing the cycle by the next parameter.

After iterating through all the combinations, the computer prints an end sign and stops. The calculation results are shown in Fig. 4 and Fig. 5

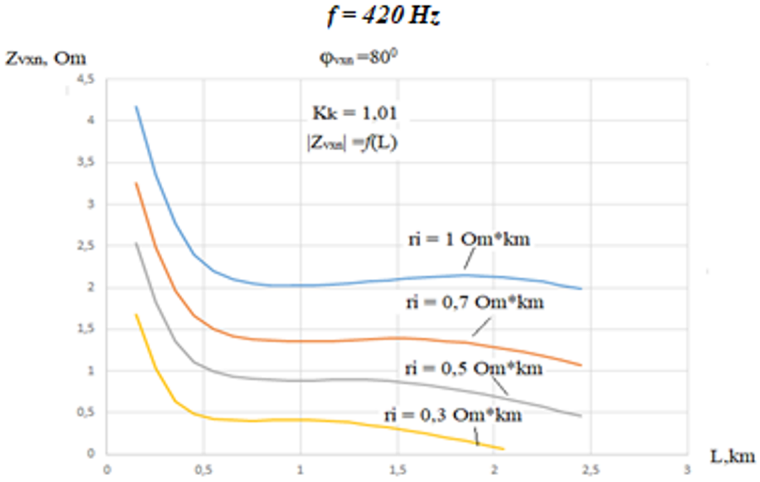

Fig.4. Graphs of dependences of the input resistances of the control sensor from the condition of providing sensitivity to a broken rail thread on the length of the circuit at a signal current frequency f = 420 Hz and ϕinb = 80^0

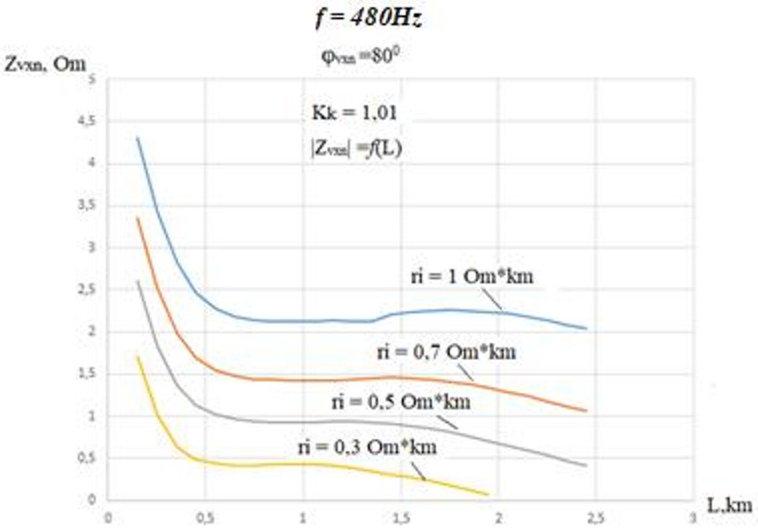

Fig. 5. Graphs of dependences of the input resistances of the control sensor from the condition of providing sensitivity to a broken rail thread on the length of the circuit at a signal current frequency f = 480 Hz and ϕinb = 80^0

From the analysis of graphs (4 - 5), we can draw the following conclusions: 1. With an increase in the length of the rail line, the resistance modules at the ends of the control sensor decrease; 2. With an increase in the insulation resistance, the resistance modules at the ends of the control sensor increase, and the length of the rail line also increases; 3. The length of the rail line also depends on the arguments of the resistances at the ends of the control sensor; 4. The parameters of the control sensor are practically independent of the frequency of the signal current; 5. Studies have shown that such control sensors can be used for crossing devices

4 Conclusion

The use of tonal jointless track circuits with current receivers will increase the safety of train traffic on sections equipped with crossings, as well as use the principle of the current receiver itself to control the speed of trains approaching the approach section at crossings.

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