Algorithms and mathematical model for determining shunt power of intelligent track section control sensor

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Abstract. The normal operating state of jointless and butt track circuits depends on the state of change in the insulation resistance; respectively, the correct choice of the maximum and minimum limit resistance characteristics should be considered. The maximum and minimum limit resistance depends on the power consumption of the unlimited track circuit in the normal and the mode of movement of the wheelset at the supply end of the rail line. The article presents a study of an intelligent track circuit without insulated joints, where logical elements replace all the equipment of mechanical and electrical energy converters. The research aims to determine the shunt that affects the definition of the movable block, respectively, the definition of the power of the shunt. The method consists in choosing a sensor, namely an intelligent track control sensor, and developing a mathematical model for determining the shunt power, which provides the influence of the shunt on the track circuit. Research carried out for track circuits with insulating joints has shown that with the value of the argument, modulus, and synthesis of the maximum-minimum limit resistance when the supply end is shunted, the maximum power will be the least minimum $R_{k_{\text{max}}}$. Because of the lack of more accurate data for an intelligent control sensor, studies were carried out.

1 Introduction

The general theory of track circuits can be mainly used in the analysis and synthesis of unlimited track circuits without insulating joints [1]. But at the same time, it is necessary to consider some specific due to the lack of insulating joints. Calculations of the coefficients of track circuits were carried out with some assumptions [2,3,5], and no method was given for their exact determination [10-18]. To determine the exact equations, it is necessary to consider jointless track circuits as unlimited asymmetric track lines, in which, firstly, the primary and secondary parameters may differ significantly from each other and, secondly, there may be moving units on adjacent track circuits.

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2 Main Part

2.1 Mathematical model of the shunt power of an intelligent control sensor

For track circuits with insulating joints, it was calculated that the power \( R_{\text{max}} \) calculated for track circuits with joints would have when \( |z|^{-|\varphi_x|} \) and \( |z|^{-|\varphi_y|} \pm 180^\circ \) , where \( z \) is the input resistance of the rail line at the beginning between the points of the beginning of the track, is the reverse and direct limit resistance \([1, 6, 7]\). In smart sensors (intelligent seamless track circuits), there is a feature that consists of calculating the maximum power at the smallest value produced by shunting the wheel sets at the beginning and end of the supply end is made taking into account the influence of two shunts by two trains \([8, 9], 19-21\) located on both sides of the supply end, as shown in the equivalent circuit of Fig. 2. To analyze a jointless unlimited track circuit when using shunt power, consider its substitution schemes in the absence of trains in Fig. 3 and Fig. 4, and in the mode of shunting the supply end Fig. 5, Fig. 6.
Fig. 3. Main substitution scheme of track circuit in normal mode.

Fig. 4. General substitution scheme for shunt power of track circuit in presence of movable unit at the supply end.

Fig. 5. Main substitution scheme of track circuit in presence of moving unit at the supply end.

Fig. 6. Substitution scheme of track circuit with shunts at the ends.
The module and argument of the limiting resistance and the values of \( x \) and \( y \), at which the smallest possible maximum shunt power of the supply end will be possible, can be determined from the substitution schemes under normal conditions (Fig. 2) and shunt mode (Fig. 5).

For the scheme presented in Fig. 3, Fig. 4 we can write:

\[ (1), (2) \]

where

\[ i_{kzib1} \]

is the current flow to an adjacent track circuit, \( i_{kzib2} \) is current flowing in its own track circuit, \( A_{tt}, B_{tt}, C_{tt}, D_{tt} \) are the coefficients of the quadripole substituting the inductor-transformer of the supply end. For the shunt power mode according to the scheme of Fig. 5, we can write:

\[ (3), (4), (5) \]

According to the above equivalent scheme in Figure 1, equations have been developed and given that, in the presence of a train at the supply end of the rail line, greatly simplify the determination of conditions that provide a large minimum possible maximum power. In this scheme,

\[ (6), (7), (8) \]

transforming equation (6), we get:

\[ (9) \]

Let us replace the quantities and their values according to equations (7) and (8), we obtain

\[ (10) \]

Or bracketing,

we get
Denoting through making a substitution in equation (11), we obtain (12).

To determine the short circuit power, the formula is given:

Substituting the value of $E$ from equation (12) into equation (13), we obtain |

or |

When $x, y = \text{const}$ in equation (15) with a change only one complex value will change.

Determination of the minimum which is the modulus of the value for a given argument, with a constant value ($\varphi_0, \varphi_{bkz}$), we determine the value of the module.

Combining the left and right sides of the equation (15), we obtain |

Having examined equation (16) for max. and min. relatively, we get:

From here |

Thus, the smallest power when shunting the supply end of the track circuit for any argument of the limiting resistance and any values of $x$ and $y$ will be subject to the condition.

To calculate the smallest shunting power of the supply end for the given values of $\varphi$, transforming it into equation (16), substituting its optimal value instead of |

It can be seen from equation (17) that with $x$, and a variable value, with an increase in the difference in arguments up to $\pm 180^0$, when shunted by a train, the maximum power takes on the smallest value. In this case, |

From this, it can be concluded that such a case does not occur practically.
\[ Z_0 = \frac{1}{\sqrt{\left| Z_0 \right|}} \]

\[ Z_{nkzi} = Z_g + \dot{Z}_o + \dot{Z}_{kzi} \]

\[ Z_0 = -\frac{Z_g \sinh(\varphi_o \pm \varphi_g) + Z_{kzi} \cosh(\varphi_o \pm \varphi_{kzi})}{\pm} \]

\[ \rightarrow \pm \frac{Z_g \sinh(\varphi_o \pm \varphi_g) + Z_{kzi} \cosh(\varphi_o \pm \varphi_{kzi})}{2} + Z_{nkzi}^2 - \cosh(Z_g + Z_{nkzi})^2 \]

\[ \frac{|1|b_{k1} + |b_{k2}|^2|2g + 2o + 2b|^2}{Z_g + 2o + 2kzi} = P_{kz} \]

\[ P_{kz} = \frac{|1|b_{k1} + |b_{k2}|^2|2g + 2o + 2b|^2 \cosh(\varphi_o \pm \varphi_{kzi})}{Z_g + 2o + 2kzi \cosh(\varphi_o \pm \varphi_{kzi})} \]

\[ Z_{ob} = Z_g + \dot{Z}_o + \frac{A_{tt} \cdot (2x + 2y + B_{tt} \cdot (2x + 2y))}{C_{tt} \cdot (2x + 2y)} \]

\[ \frac{x + 2y}{x + 2y} = l \cdot z \]

\[ A_{tt} \cdot z = k_1 \cdot B_{tt} = k_2 \cdot C_{tt} \cdot z = k_3 \cdot D_{tt} = k_4 \cdot \dot{Z}_o + \dot{Z}_o = k_5 \]

\[ \dot{Z}_{ob} = k_5 \frac{k_1 \cdot l + k_2}{k_3 \cdot l + k_4} \]

\[ \dot{Z}_{ot}(k_3 \cdot l + k_4) = k_5(k_3 \cdot l + k_4) + k_1 \cdot l + k_2 \]
Having made transformations, we get the following:

\[ \hat{z}_{ob} (k_3 * l + k_4) = SL + T \]

\[ S = k_5 k_3 + k_1 \]

After transformations into equations (25), we obtain the following:

\[ Z_{ob}^2 = \frac{S^2 l^2 + 2ST\cos(\varphi_+ \pm \varphi_+ ) + T^2}{k_3^2 l^2 + 2k_3 k_4 \cos(\varphi_+ \pm \varphi_+ ) + k_4^2} \]

Having examined equation (26) for max. and min. concerning \( l \), we get:

\[ l = \frac{V_1}{2} \pm \frac{\sqrt{V_2^2}}{4} - V_0 \]

Substituting \( V_1 \), \( V_2 \), and \( Z_0 \) for different values, we obtain an expression that allows us to determine the value of \( l \).

To determine the value when changing under various conditions, we substitute a certain value of \( l \) into:

\[ Z_r \quad Z_o \quad \varphi_+ \quad x \quad l \quad y \]

\[ l = \frac{z + 2y}{2 + x + 2y} = l \ast z \]

3 Result and discussion

The growing needs of the industry in rail transportation determine the design of modern distillation systems railway automation, the introduction of new methods, to date, on the used tone rail circuits, the tasks of their analysis and are especially relevant since safety and throughput are most ensured by the performance of the work of intelligent track circuits. In the study of intelligent track circuits, a deep synthesis is carried out, taking into account the features and disturbing factors of influence; mathematical modeling and theoretical results are carried out, and the following conclusions can be drawn from them:

Considering the requirements for intelligent track circuits, the most difficult thing is to ensure the safety of transportation, depending on the characteristics of the operation of rail lines, the elements used in intelligent track circuits, their parameters, and damage.

One of the methods has been developed, simulation modeling, which allows considering and expanding the details of the theory and analysis of intelligent track circuits, as well as applying various methods of using system elements and their structure, and using them in modeling electrical circuits.

On Fig. 7, a block scheme of a simulation model of an adaptive jointless tonal frequency track circuit, depending on the power resistance of the shunt of conjugated track circuits, and a program is presented.
4 Conclusions
The conducted studies allow to accurately determine the shunt power that affects the definition of the mobile unit and eliminate the factors of failure to determine the unit on the site. The data show that using smart sensors increases the reliability and safety of the shunt effect on the jointless adaptive track circuit.

References

1. Aliev R., Aliev M., Tokhirov E. Analysis, development of a model and an algorithm in the concept of the growth of tone jointless rail circuits // Transportation Research Procedia, 63 (2022)
2. Aliev R., Aliev M. Methods calculation for station tonal rail circuits with current receiver // Transportation Research Procedia, 63 (2022)


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