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Trends in Improving Sensors for Controlling the Condition of Track Sections

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Abstract. Various principles can be used to implement intelligent track circuits: voltage regulation of the power supply, compensation methods for switching on rail lines and track circuit devices, receiver sensitivity adjustment, comparison of two electrical parameters of one, two, or more track circuits, as well as a combination of these methods. At present, such improvement of track circuits is becoming relevant, which would make it possible to exclude from the circuits one of the most unreliable elements - an insulating joint, use a modern microprocessor element base in devices for monitoring the state of track sections, thus ensure their reliable operation. This will significantly reduce the costs of building and operating interval control systems and increase train traffic safety. These requirements are met by intelligent track circuits, which consider the current value of the insulation resistance, the rate of change of this resistance, and the longitudinal asymmetry.

1 Introduction

A national transport policy of many developed countries is currently based on the development and promotion of intelligent transport systems (ITS). ITS is considered a powerful tool to solve the most urgent problems of the transport sector. In the first note, the following issues: - an unacceptable level of casualty's results from vehicle accidents - delay of passengers and cargo turnover - insufficient performance of the transport system - an increase in energy consumption, the negative impact on the environment and others. Development and the use of ITS is an incentive for the development of innovative technologies in several industries. Among them are, for example, such sectors and innovative ITS technologies: -Reduce the risk and reduce the impact of natural and man-made disasters, - the technology of intelligent monitoring and control systems; - the creation of new transport systems and control technology; - the creation of energy-efficient transportation, distribution and consumption of energy in the field of railway transport; - the creation of innovative technologies and processing systems, storage, transmission and protection of information; - the creation of innovative technologies and production software systems, etc. The intelligent systems performed (automatic, automatic, or formalized, logically) the formation of information and mathematical models of the environment and the functioning of objects, automatic parameter identification, and adaptation of appropriate mathematical models.

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An important and urgent problem is developing such methods and devices for monitoring the state of rail lines, which reduce the minimum allowable insulation resistance value, increase shunt sensitivity, remove the insulating joints from the track circuits, simplify their maintenance [1]. Using tone track circuits without insulating joints does not solve the problem because they have short length, large quantity floor appliances [2]. Hence, track control systems must be implemented with the help of fundamentally new methods, which increase the length of the rail line, reduce construction and operating costs, reduce the minimum allowable insulation resistance, increase shunt sensitivity, and reduce floor appliances [3, 4].

2 Methods

2.1 Model of a rail line with a chains connection of quadripoles with distributed parameters of a track circuit with an adaptive receiver

The calculated basic substitutions scheme of a rail line with a chain connection of quadrupoles with distributed parameters is shown in Fig. 1

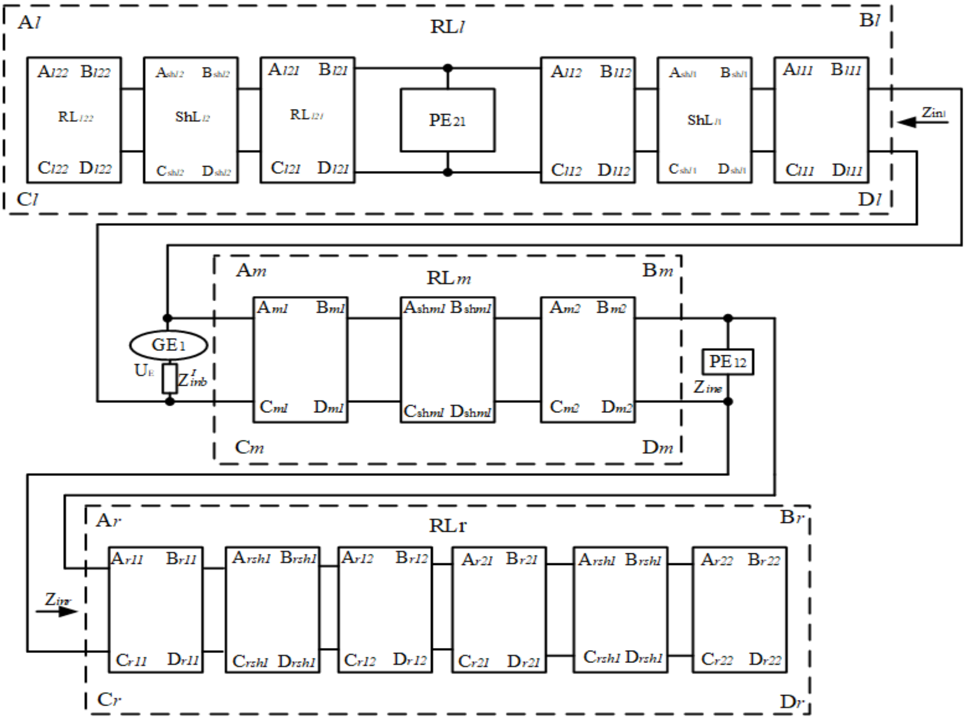

Fig. 1. Base the scheme substitutions of a track circuit with a chain connection of quadripoles rail lines

Each of the rail line sections between the place where the devices are connected and the train shunt and the shunts themselves is represented by four-pole devices with distributed parameters. Quadripoles equivalent to distributed train shunts have the designations ShL_{L2}, ShL_{L1}, ShL_{Lm},ShL_{Ll}, ShL_{Lr}, and their coefficients A_{shl2}, B_{shl2}, C_{shl2}, D_{shl2}. The values of the coefficients of quadripoles rail lines are determined by the well-known formulas [6-7]:

$$A = D = ch\gamma l + sh\gamma l;$$

$$B = Z_w \cdot sh\gamma l + Z_e ch\gamma l;$$

$$C = \frac{2}{Z_в}(ch\gamma l + sh\gamma l) \qquad (1)$$

where z is specific resistance rails,
r_i is specific insulation resistance
The values of the coefficients of the train shunts for quadripoles connections are determined by the formulas:

$$A_n = D_n = ch\gamma_n l_n + sh\gamma_n l_n;$$

$$B = Z_w \cdot sh\gamma_n l_n + Z_e ch\gamma_n l_n;$$

$$C_n = \frac{2}{Z_{wn}}(ch\gamma_n l_n + sh\gamma_n l_n) \qquad (2)$$

$$\gamma = \sqrt{\frac{Z^I}{r_n}};\ Z_{wn} = \sqrt{Z^I r_n}. \qquad (3)$$

where r_r is specific distributed shunt resistivity

$$r_r = R_{shw} \cdot W \qquad (4)$$

R_{shw} is shunt resistance from one wagon
W is quantity wagons for one km $(1/km)$,
l_t is train length (km);
z^I is fetched specific resistance of the rail, which considers the spreading of current over the structure of the rolling stock.
This resistance is calculated by the formula $z^I = zk_p$, where k_p is coefficient taking into account current spreading along the structure of the rolling stock.
To determine the coefficients of quadripoles $RL_{l(left)}$, $RL_{m(middle)}$, $RL_{r(right)}$, multiply the matrices included in these rail lines:

$$\begin{Vmatrix} A_l & B_l \\ C_l & D_l \end{Vmatrix} = \begin{Vmatrix} A_{l11} & C_{l11} \\ B_{l11} & D_{l11} \end{Vmatrix} \times \begin{Vmatrix} A_{shl1} & B_{shl1} \\ C_{shl1} & D_{shl1} \end{Vmatrix} \times \begin{Vmatrix} A_{l12} & B_{l12} \\ C_{l12} & D_{l12} \end{Vmatrix} \begin{Vmatrix} 1 & 0 \\ \frac{1}{Z_{ine}} & 1 \end{Vmatrix} \times \begin{Vmatrix} A_{l21} & B_{l21} \\ C_{l21} & D_{l21} \end{Vmatrix} \times$$
$$\times \begin{Vmatrix} A_{shl2} & B_{shl2} \\ C_{shl2} & D_{shl2} \end{Vmatrix} \times \begin{Vmatrix} A_{l22} & B_{l22} \\ C_{l22} & D_{l22} \end{Vmatrix} \qquad (5)$$

$$\begin{Vmatrix} A_r & B_r \\ C_r & D_r \end{Vmatrix} = \begin{Vmatrix} A_{r11} & C_{r11} \\ B_{r11} & D_{r11} \end{Vmatrix} \times \begin{Vmatrix} A_{shr1} & B_{shr1} \\ C_{shr1} & D_{shr1} \end{Vmatrix} \times\times \begin{Vmatrix} A_{r12} & B_{r12} \\ C_{r12} & D_{r12} \end{Vmatrix} \times \begin{Vmatrix} A_{r21} & B_{r21} \\ C_{r21} & D_{r21} \end{Vmatrix} \times$$
$$\times \begin{Vmatrix} A_{shr2} & B_{shr2} \\ C_{shr2} & D_{shr2} \end{Vmatrix} \times \begin{Vmatrix} A_{r22} & B_{r22} \\ C_{r22} & D_{r22} \end{Vmatrix} \qquad (6)$$

$$\begin{Vmatrix} A_m & B_m \\ C_m & D_m \end{Vmatrix} = \begin{Vmatrix} A_{m11} & C_{m11} \\ B_{m11} & D_{m11} \end{Vmatrix} \times \begin{Vmatrix} A_{shm} & B_{shm} \\ C_{shm} & D_{shm} \end{Vmatrix} \times \begin{Vmatrix} A_{m12} & B_{m12} \\ C_{m12} & D_{m12} \end{Vmatrix} \qquad (7)$$

It should be noted that in the RL_r rail line, the second track generator is not taken into account since its internal resistance at the frequency of the first generator is large enough.

Influence of rail lines RL_l and RL_r replace with input resistances Z_{inl} and Z_{inr} respectively (see figure 2)

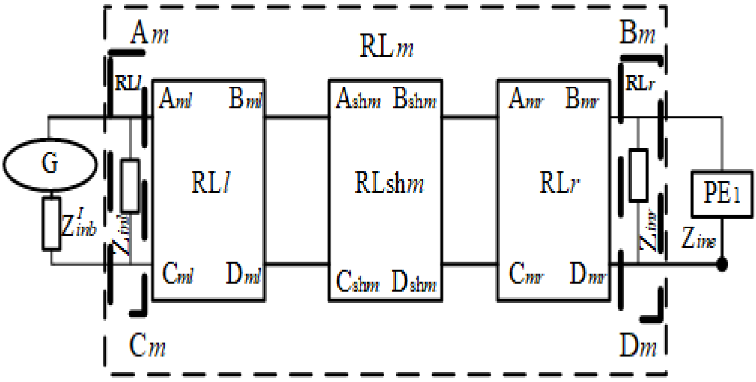

Fig. 2. Calculated substitutions scheme of a track circuit with chains connection of four-poles of rail lines

Quadrupole RL_m with input resistances Z_{inl} and Z_{inr} can be converted to an equivalent rail line RL_e (Figure 3) with coefficients$A_e, B_e,\ C_e,\ D_e$.

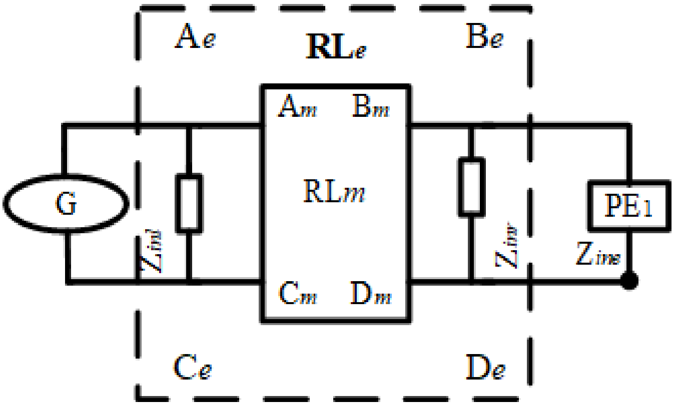

Fig. 3. General substitutions scheme of a track circuit with chain connection of four-pole of rail lines

Coefficients equivalent rail line RL_e $A_e, B_e,\ C_e$ and D_e are determined by the equations:

$$A_e = A_m + \frac{B_m}{Z_{inr}};\ B_e = B_m;$$

$$C_e = C_m + {}^{A_m}/_{Z_{inl}} + (D_m + {}^{B_m}/_{Z_{inl}})/Z_{inr};$$

$$D_e = D_m + {}^{B_m}/_{Z_{inl}} \qquad (8)$$

The given factors can be used to calculate track circuits of the controlled area.

3 Result and Discussions

To research the track circuits, the scheme substitution of the rail line in normal and shunt modes should be represented by one generalized scheme, with the ability to set an uneven change in insulation resistance along a rail line and move trains of any length. Controlling the state of the rail line track circuits can be carried considering states and parameters of other rail lines. Therefore, scheme substitution must represent the cumulative number of rail lines. Such cumulative rail lines will be called the control zone (CZ). The control zone may include compactly located rail lines of the station or stage, which are jointly controlled.

The block diagram of the algorithm for calculating a rail line with a chain connection of quadripoles is shown in Fig. 4. It contains the following block diagrams:

1 is program launch;

2 is automatic input of a standard package of initial data;

3 is manual correction of initial data;

4 is display of current parameters;

5 is calculation of the first and second track circuits;

6 is calculation of third track circuits;

6.1 is insulation resistance calculation;

6.2 is calculation of the coordinates of the rolling stock;

6.3 is calculation of the input resistance of the Z_{inl};

6.4 is calculation of the input resistance of the Z_{inr};

6.5 is calculation of coefficients of quadripoles of the middle rail line RL_m;

6.6 is calculation of the coefficients of the equivalent quadripoles rail line RL_e;

6.7 is calculation of the current of the equivalent power supply and the voltage at the input of the equivalent receiver;

7 is calculation of the fourth, fifth and sixth track circuits;

8 is control of the exit of trains from the controlled section;

9 is completion of work.

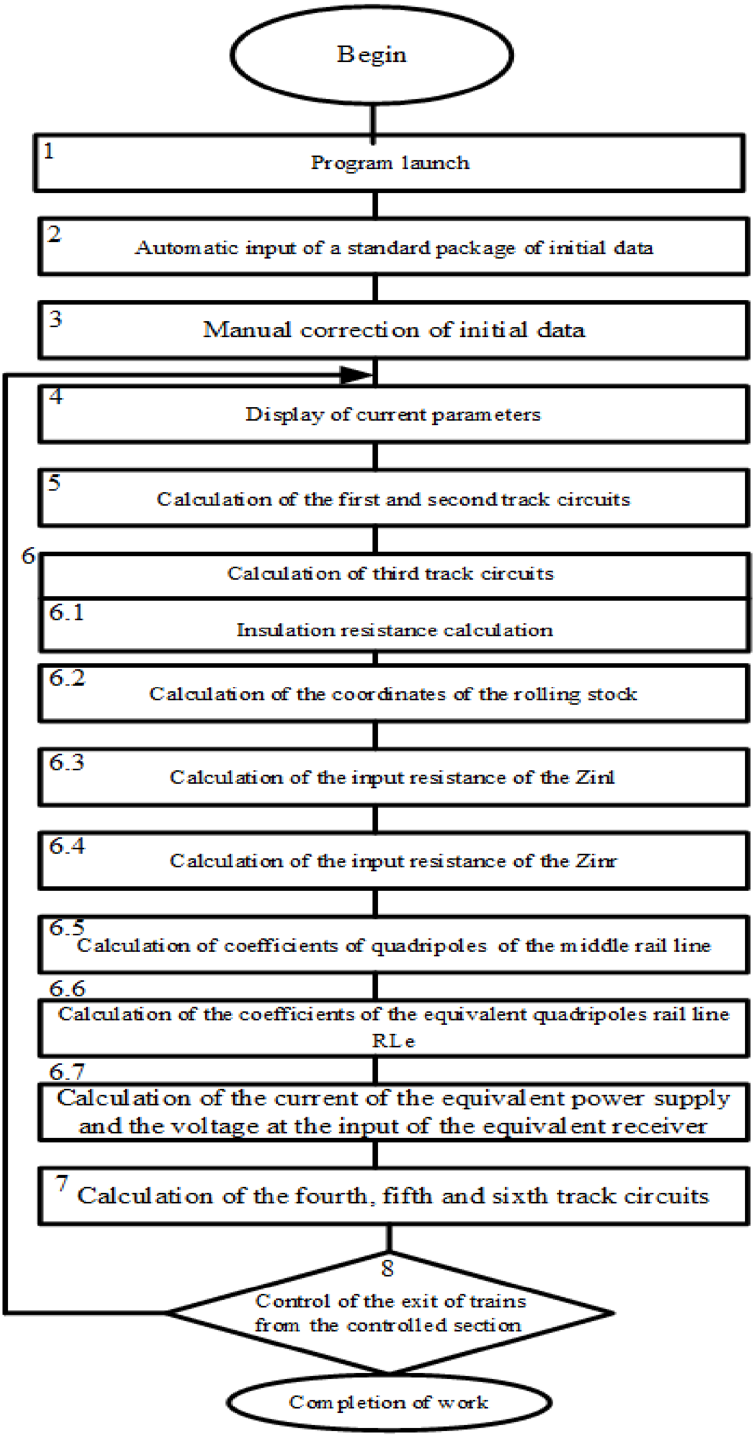

Fig. 4. Algorithm of the program for calculating track circuits with a chain connection of quadripoles rail lines

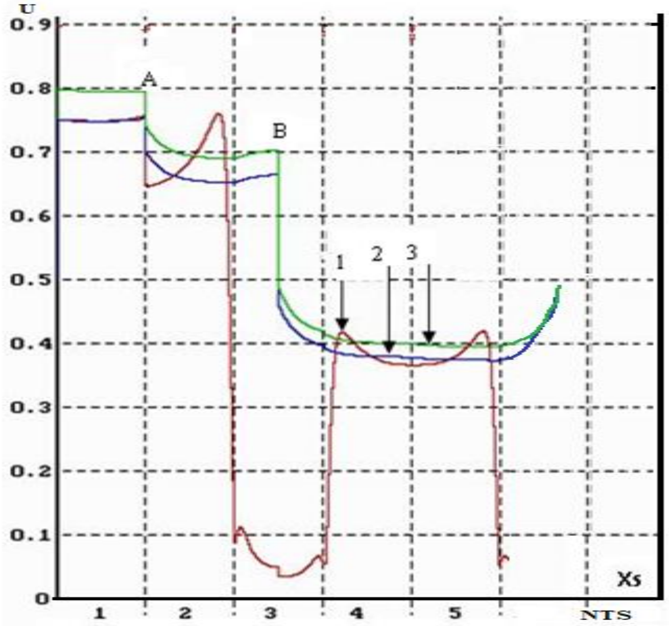

Fig. 5. Graphs of stress dependences of the third track section from the coordinate of one standard shunt at dynamic change insulation resistance from 1om*km and below.

By figure 5 seen, that the change in the insulation resistance did not cause a violation of the reliability of the monitoring of the track sections. Analysis of the operation of the track circuit on a computer showed that the proposed method would monitor the state of track sections even with a decrease in insulation resistance, which significantly increases train traffic safety.

4 Conclusions

Research on intelligent TCs has a series of differences. The worst rail line parameters can be conditions not coinciding with those known for track circuits with relay action receivers. The worst conditions are not the minimum insulation resistance in normal mode and the maximum in the shunt, and the speed of change of insulation resistance, range, and initial value of insulation resistance. The research subject can be the maximum permissible length of rail lines, minimum permissible insulation resistance, normative (new normative) resistance of the train shunt. The parameters of the input resistances at the ends in the first approximation can be taken in the same way as in the tonal track circuits. As research deepens for each specific length of the rail line, minimum permissible insulation resistance can have adjusted values of input resistances by the rail line ends.

The model makes it possible to research ATC in conditions as close as possible to operational conditions.

References

1. Arkatov, V.S., Arkatov, Yu.V., Kazeev, S.V., Obodovsky, Yu.V., *Track chains of main railways*. 3rd edition revised and enlarged, M, JVS Mission-M, 496, (2006)
2. Aliev R.M. Determination of optimal parameters of continuous welded rail circuits with a potential receiver, *Bulletin of TSTU* **4**, pp. 50-54, (2015)

3. Aliev R. M., Aliev, M.M. and Tokhirov E.T 2020 Methodology for Determining the Optimal Values of Resistance at the Ends of the Jointless Track Circuit with Considering Twofold Shunting *International Journal of Emerging Trends in Engineering Research, IJETER* **8** (9), pp. 5048-5052, (2000)
4. Gregor Theeg, Sergej Vlasenko, *Railway Signalling and Interlocking*. A DVV Media Group publication. Eurailpress, p. 448, (2009)
5. Belyakov I.V., Neklyudov, Yu.N. Microprocessor-based unified automatic blocking system AB-UE // Journal "*Automation, communication and informatics*" **6**, pp. 23-25, (2002)
6. Aliev R.M., Tokhirov E.T., Aliev M.M. The Mathematical Model of the Sensor for Monitoring the State of the Track Section with Current Receivers *IJRTE* **8**(5), pp. 5634-5637, (2020)
7. Arkatov V.S. *Rail chains of the main railways*, M.: Transport, p. 384, (1996)
8. Kravtsov Yu.A. and Nesterov V.L., Lekuta G.F. *Systems of railway automatics and telemechanics* (Textbook for higher educational institutions of railway transport.) M.: Transport, p. 400, (1996)
9. Bezrodny B.F., Denisov B.R., Kultin V.B., Rastegaev S.N. Automation of calculation of parameters and verification of the mall, *Magazine "Automation, communication and informatics*», **1**, pp. 15-17, (2010)
10. Polevoy Y.I. Relative rail circuit for areas with rapidly changing insulation resistance, Actual problems of railway transport development. Materials of the regional scientific and practical conference, Samara State Academy of Railways **2**, pp. 182 – 186, pp. (2004)
11. Aripov N., Aliyev R., Baratov D., Ametova E. Features of Construction of Systems of Railway Automatics and Telemechanics at the Organization of High-Speed Traffic in the Republic of Uzbekistan *Procedia Engineering* **134**, pp. 175-180, (2016)
12. Polevoy Y.I. Rail line models. Monograph, Samarsk. State Univer. ways of communication, Samara: SamGUPS, p.75, (2010)
13. Polevoy, Y.I. Improvement of devices for monitoring the state of railway track sections, Samara: SamGAPS, p.133. (2005)
14. High-speed railway lines in the world: *Railways: present and future*, **3**, pp. 167-180, (2007)
15. Further increase in train speed at JR East: [tasks, prospects of the railway. company JR East (Japan), serving the network of high-speed communications Shinkansen] // *World Railways*. **10**, pp. 46-50, (2009