Intelligent track circuit development concept

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Abstract - Currently, becomes actual such improvement of track circuits, which would allow excluding from the chains one of the most unreliable elements – insulating joint, use in devices for controlling the state of track sections a modern microprocessor element base, thereby ensure their reliable operation. This will significantly reduce the cost of construction and operation of interval control systems and of exploitation of interval control systems and will increase the safety of train traffic. From all of the above expound follow, that an important and urgent problem is the development of such methods and devices for controlling the condition of rail lines, which reduce the minimum allowable insulation resistance, increase shunt sensitivity, remove insulating joints from track circuits, simplify their maintenance. The use of tonal track circuits without insulating joints does not solve the problem, as they have a small length, a more quantity floor devices. All this allows us to conclude, that controlling systems for rail lines should be realized with help using fundamentally new methods, which contribute to the increase in the length of the rail line, reducing construction and operating costs, reduction of the minimum allowable insulation resistance, increased shunt sensitivity, reduction of floor devices.

Keywords - Tonal rail chain without isolating joints, potential receiver, current receiver, equivalent scheme, shunt sensitivity.

1. INTRODUCTION

One of the standard parameters in the design and exploitation of rail circuits with insulating joints is the specific resistance of ballast insulation, which is taken ri = 1 Ohm * km [1, 7], but as shown [3] measurements carried out on different sections of the railway of Uzbekistan, it fluctuates widely limits and depends on the state of climatic conditions, i.e. one of the main indignation factors, adversely affecting the operation of track circuits, is the insulation resistance of rail lines, which changes continuously throughout the year and day. Thus, an important factor. affecting the reliability of controlling the states of the rail line, is the considered range of variation of the insulation resistance, the boundaries of which and the rate of change of the insulation resistance fluctuate within wide limits, as well as longitudinal asymmetry of insulation resistance.

Implementation of the ATC using a relay receiver is difficult, since scheme solutions are extremely cumbersome, unreliable and do not allow flexible adaptation to the value of insulation resistance [5]. Microelectronic element base contributes to the implementation of smooth adaptation of the receiver sensitivity to the insulation resistance, comparison of electrical parameters with the required accuracy, flexible change of the control method algorithm. At the same time, such an implementation requires the development and manufacture of complex microelectronic circuits.

In this situation, the most attractive is the implementation of the principles of the ARC operation based on microprocessor technology with digital signal processing [4] the presence of multiple shunts, dynamics of changes in insulation resistance, longitudinal asymmetry of insulation resistance. New models of rail lines are required, which should take into account the above factors [5].

Until now time not clarified the coefficients of four-pole jointless rail circuits, when investigating such circuits, are used calculating approximate methods the coefficients of a rail four-pole, based on the replacement of adjacent track circuits by input lumped resistances and the approximate equations of these coefficients are obtained, which did not allow taking into account the actual distribution of currents and voltages along adjacent track lines. because of the lack of exact equations not even an estimate of the error at their use was made.

The introduction of tonal track circuits requires high costs, as their length is limited and at low ballast resistance they begin give failures in work [6]. Therefore, this requires solving issues related to the development of scientific approaches and practical recommendations for creating continuous welded relative track circuits with adaptive receiver or intelligent track circuits

2. METHODOLOGY

At the analysis and synthesis of track circuits without insulating joints in the main the general theory of track circuits can be used. However, it is necessary to take into account some specific features, due to the lack of insulating joints. The calculations of the rail circuit coefficients were carried out with a number of assumptions [6; 8] and no was given method for their precise determination. To determine the exact equations, it is necessary to consider jointless rail circuits as unbounded asymmetric rail lines [9], at which, first, the primary and secondary parameters can differ significantly from each other [10] and secondly, moving units can be located on adjacent track circuits.

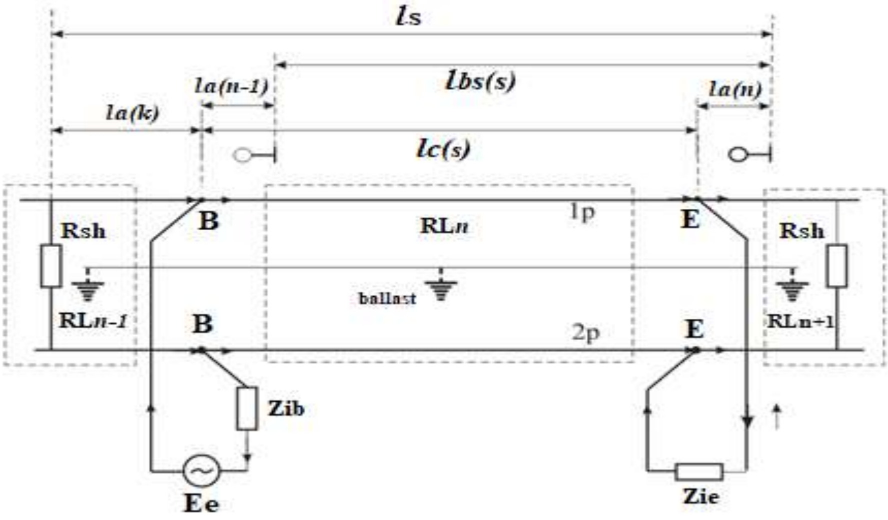

Figure 1. The main substitution schema of a jointless track circuit

With considering these assumptions general scheme substitutions of a track circuit without insulating joints in normal mode can be represented in the form of a diagram shown in Fig. 1.

In this scheme, points B and E show the connection points for the equipment of the supply and ends of relay of the rail circuit. The distance between points "B" and "E" is called the design length of the continuous track circuit $l_{c(s)}$.

Distances $l_{a(n-1)}$ and $l_{a(n)}$ represent the zones of additional shunting of the RL*n* rail line, respectively, at the beginning and at the end of the rail line from the shunts of the departing and approaching trains to the rail line. Auto block traffic light can be set at a distance greater than $l_{a(n)}$, so that the switching of the traffic light indication to prohibiting is excluded when the train approaches it. The length of the additional shunting zones is maximum at the minimum insulation resistance of the rail line, when the voltage on the track receiver is minimal, and minimum - at maximum insulation resistance when the voltage on the track receiver is at maximum in normal mode. With an increase in the frequency of the signal current, the resistance of the rail lines increases, and the length of the additional shunting zones is reduced.

This scheme, as can be seen from the figure, differs significantly from the substitution scheme of the rail circuit with insulating joints in Fig. 2.

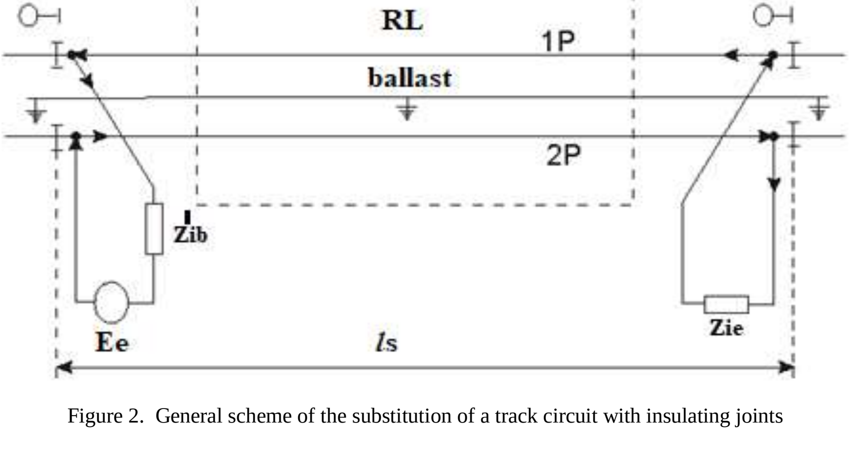

Figure 2. General scheme of the substitution of a track circuit with insulating joints

Therefore, for the analysis and synthesis of rail circuits without insulating joints, first of all, it is necessary to derive equations for calculating the coefficients the quadripole, replacing a rail line.

Coefficients of a quadripole of a jointless track circuit (JTC) can be determined on the basis of the equations for the distribution of currents and voltages along the rail line according (Fig. 3) with initial conditions different from the conditions adopted for track circuits with insulating joints.

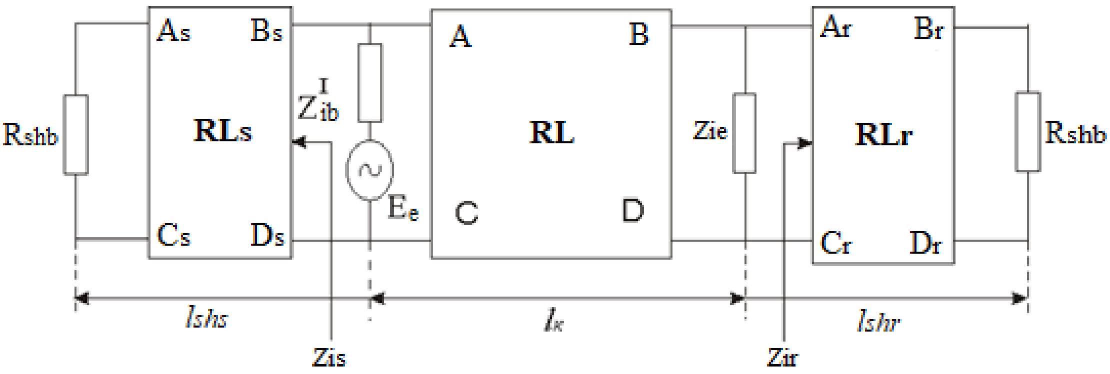

Figure 3. General scheme of the substitution jointless rail circuit

Comparing the diagram shown in figure 1 with the basic scheme substitution of track circuits with insulating joints (TC) (Figure 2) it can be argued:

1. Scheme jointless track circuit (Figure 1) and track circuit with insulating joints (Figure 2) differ significantly from each other and to use the coefficients of the rail quadripole of the TC for the analysis and synthesis of the JTC cannot be used. Therefore, for the analysis and synthesis of rail circuits without insulating joints, first of all, it is necessary to derive equations for calculating the coefficients of a quadripole replacing a jointless rail line.
2. In normal mode, due to the absence of insulating joints, current spreading along adjacent rail lines will require an increase in the value of Ee, which ultimately will increase the K_{tmax} value and decrease value the K_{shb} and $K_{m(mainstay)}$.

3. The normal operating mode of the RLn track circuit will be observed not only when all track lines are free, but also in the event that one of the adjacent rail lines is occupied by a mobile unit, at what its shunt will be removed from the point of connection of the track circuit equipment at a distance greater than l_{osh}. The l_{ash} area is called the additional shunting zone. The indicated zones are located both at the supply l_{ashs} and at the relay l_{ashe} ends of the track circuit. When approaching two trains the normal mode work of the RLn track circuit will depend on the presence of train shunts on the adjacent sections of RLn + 1 and RLn-1. In this case, the values l_{ashs} and l_{ashe} can have a maximum value.

4. The shunt mode of operation of the RLn track circuit will also depend on the presence of shunts both on RLn and on a part of adjacent rail lines. The shunting zone $l_{sh} = l_{ashe} + l_k + l_{ashs}$ is called the train length of the rail circuit. When the train is on an adjacent track circuit, a complex shunt is connected to the equipment connection points $Z_{sh} = \mathrm{R_{shn}} + \mathrm{z} * l_{ashe}$ or $Z_{sh} = \mathrm{R_{shn}} + \mathrm{z} * l_{ashs}$. For thereof that the train does not block the traffic light itself when approaching the track circuit, the traffic light must be installed in the direction of the train at a distance l_{dshk}.

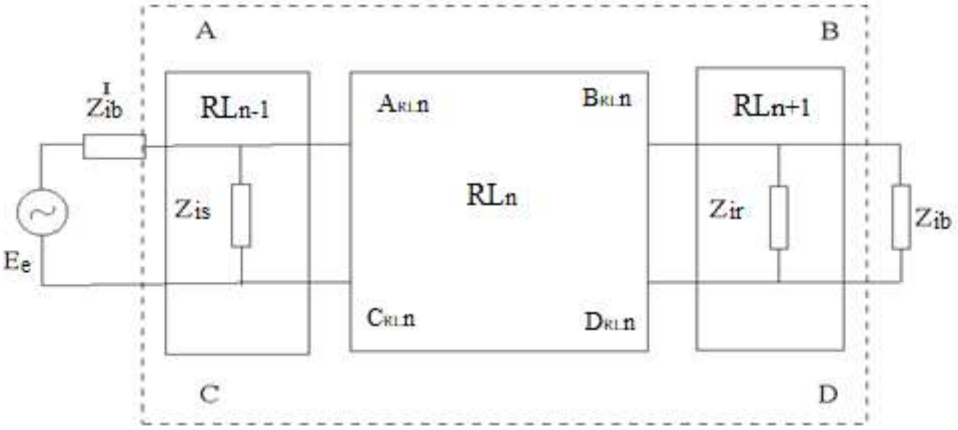

Figure 4. Transformed scheme of the replacement of a jointless track circuit.

Coefficients of a rail quadripole for a jointless rail circuit A, B, C and D are obtained after matrix multiplication:

$$\begin{Vmatrix} A & B \\ C & D \end{Vmatrix} = \begin{Vmatrix} A_{\mathrm{RLn-1}} & B_{\mathrm{RLn-1}} \\ C_{\mathrm{RLn-1}} & D_{\mathrm{RLn-1}} \end{Vmatrix} * \begin{Vmatrix} A_{\mathrm{RLn}} & B_{\mathrm{RLn}} \\ C_{\mathrm{RLn}} & D_{\mathrm{RLn}} \end{Vmatrix} * \begin{Vmatrix} A_{\mathrm{RLn+1}} & B_{\mathrm{RLn+1}} \\ C_{\mathrm{RLn+1}} & D_{\mathrm{RLn+1}} \end{Vmatrix} \tag{1}$$

where

$$A_{\mathrm{RLn}} = ch\gamma l;\ \mathrm{B}_{\mathrm{RLn}} = z_w * sh\gamma l;\ \mathrm{C}_{\mathrm{RLn}} = sh\gamma l \frac{1}{z_w};\ D_{\mathrm{RLn}} = ch\gamma l.$$

$$A_{RLn-1} = 1;\ B_{\mathrm{RLn-1}} = 0;\ C_{\mathrm{RLn-1}} = 1/z_{is};\ D_{\mathrm{RLn-1}} = 1.$$

$$A_{\mathrm{RLn+1}} = 1;\ B_{\mathrm{RLn+1}} = 0;\ C_{\mathrm{RLn+1}} = 1/z_{ir};\ D_{\mathrm{RLn+1}} = 1.$$

$$Z_{ir} = z_{wr} * \frac{R_{shb} * ch\gamma_r l_{shr} + z_{ir} sh\gamma_r l_{shr}}{R_{shb} * sh\gamma_r l_{shr} + z_{ir} ch\gamma_r l_{shr}};$$

$$Z_{is} = z_{ws} * \frac{R_{shb} * ch\gamma_s l_{shs} + z_{is} sh\gamma_s l_{shs}}{R_{shb} * sh\gamma_s l_{shs} + z_{is}\, ch\gamma_s l_{shs}}.$$

z_{wr}, z_{ws} is wave impedances of rail lines adjacent to the relay and supply ends, respectively;
γ_r and γ_s are constant propagation of rail lines adjoined respectively are relay and supply ends;
l_{shr}, l_{shs} are distance to the place of imposition of standard shunts.
After multiplying the matrices, we get:

$$\mathrm{A} = ch\gamma l + \frac{z_w}{Z_{ir}} sh\gamma l;$$

$$\mathrm{B} = z_w * sh\gamma l;$$

$$\mathrm{C} = \frac{sh\gamma l}{z_w} + \frac{ch\gamma l}{Z_{is}} + \frac{z_{\text{В}} sh\gamma l}{Z_{ir} * Z_{is}} + \frac{ch\gamma l}{Z_{ir}};$$

$$\mathrm{D} = ch\gamma l + \frac{z_w}{Z_{is}} sh\gamma l. \tag{2}$$

For a number of special cases, the calculated equations for the coefficients of a rail quadripole are greatly simplified and take the form convenient for practical calculations:

a) if we take Rsh = Rshn = 0, then:

$$Z_{ir} = z_{ir} * th\gamma_r l_{shr};$$

$$Z_{is} = z_{is} * th\gamma_s l_{shs};$$

$$\mathrm{A} = ch\gamma l + \frac{z_w}{Z_{ir} th\gamma_r l_{shr}} sh\gamma l;$$

$$\mathrm{B} = z_w * sh\gamma l;$$

$$\mathrm{C} = \frac{sh\gamma l}{z_w} + \frac{ch\gamma l}{Z_{is} th\gamma_s l_{shs}} + \frac{z_w sh\gamma l}{Z_{is} th\gamma_s l_{shs} * Z_{ir} th\gamma_r l_{shr}} + \frac{ch\gamma l}{Z_{ir} th\gamma_r l_{shr}};$$

$$\mathrm{D} = ch\gamma l + \frac{z_{\text{В}}}{Z_{is} th\gamma_s l_{shs}} sh\gamma l. \tag{3}$$

b) at presence at the supply end the rail circuit are insulating joints and choke-transformers of zis = ∞:

$$A = ch\gamma l + \frac{z_{\text{В}}}{Z_{is} th\gamma_s l_{shs}} sh\gamma l;$$

$$\mathrm{B} = z_w * sh\gamma l;$$

$$C = \frac{1}{Z_w} sh\gamma l + \frac{\mathrm{ch}\gamma l}{Z_{is} th\gamma_s l_{shs}};$$

$$D = ch\gamma l. \tag{4}$$

v) at presence at the relay end the rail circuit are insulating joints and choke-transformers of zir = ∞:

$$A = ch\gamma l;$$

$$\mathrm{B} = z_w * sh\gamma l;$$

$$C = \frac{1}{Z_w}\left(sh\gamma l + \frac{ch\gamma l}{Z_{ir} th\gamma_r l_{shr}}\right);$$

$$D \ = ch\gamma l + \frac{z_{\text{В}}}{Z_{ir} th\gamma_r l_{shr}} sh\gamma l. \qquad (5)$$

g) at finding one a moving unit on an adjacent rail line at the relay end:

$$\text{A} = ch\gamma l + \frac{z_{\text{В}}}{Z_{ir} th\gamma_r l_{shr}} sh\gamma l;$$

$$\text{B} = z_w * sh\gamma l;$$

$$\text{C} = \frac{sh\gamma l}{z_w} + \frac{ch\gamma l}{Z_{is}} + \frac{z_{\text{В}} sh\gamma l}{Z_{ir} th\gamma_r l_{shr} * Z_{is}} + \frac{ch\gamma l}{Z_{ir} th\gamma_r l_{shr}};$$

$$\text{D} = ch\gamma l + \frac{z_w}{Z_{is}} sh\gamma l. \qquad (6)$$

e) on an adjacent rail line at the supply end:

$$\text{A} = ch\gamma l + \frac{z_w}{Z_{ir}} sh\gamma l;$$

$$\text{B} = z_w * sh\gamma l;$$

$$\text{C} = \frac{sh\gamma l}{z_w} + \frac{ch\gamma l}{Z_{is} th\gamma_s l_{shs}} + \frac{z_{\text{В}} sh\gamma l}{Z_{is} th\gamma_s l_{shs} * Z_{ir}} + \frac{ch\gamma l}{Z_{ir}};$$

$$\text{D} = ch\gamma l + \frac{z_w}{Z_{ir} th\gamma_r l_{shr}} sh\gamma l. \qquad (7)$$

3. DISCUSSION AND RESULT

To research the ITC, 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 of the state of the rail line ITC can carried with considering states and parameters of other rail lines, therefore, scheme substitution must represent the cumulative of a number of rail lines. Such of cumulative of 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 peculiarity of monitoring the state of rail lines by ITC methods is that at the same time must the considering values of the voltage of the receiving ends and the currents of the supply ends of one or several rail lines of the control zone, what can be done with the participation of a computer according to the program, corresponding to the method of controlling the state of the rail line.

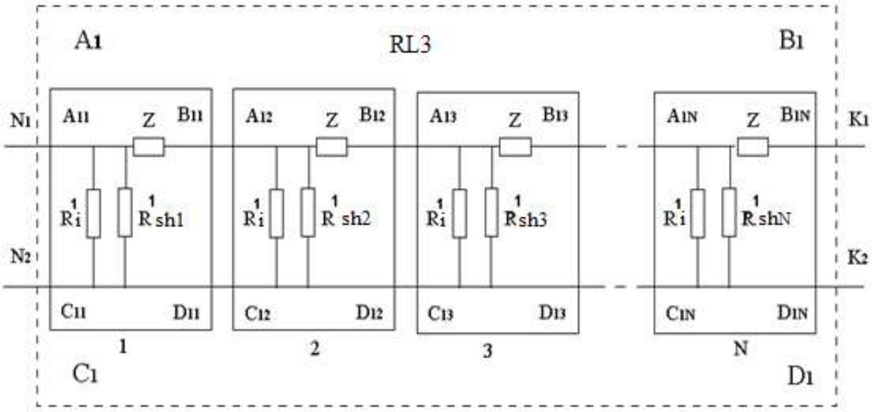

Figure 5. Scheme substitution of the rail line RL3 with discrete-distributed parameters

The calculation of the track circuit should be made taking into account the influence of other track lines. With a signal current frequency above 400 Hz and a rail line length of 500 m or more is observed influence from two track lines on either side of the controlled track circuit. For the calculation of the rail circuit, a basic substitution schema of the rail line is proposed (Fig. 6). On this scheme the basic is rail line RL3, and rail lines RL2, RL4 are presented as influencing. The base scheme uses the designations of the coefficients of the quadripoles A2,… D4, insulation resistance R*I2*,…, R*I4* and shunts R*Sh2*,… R*ShN4* in accordance with figure 5.

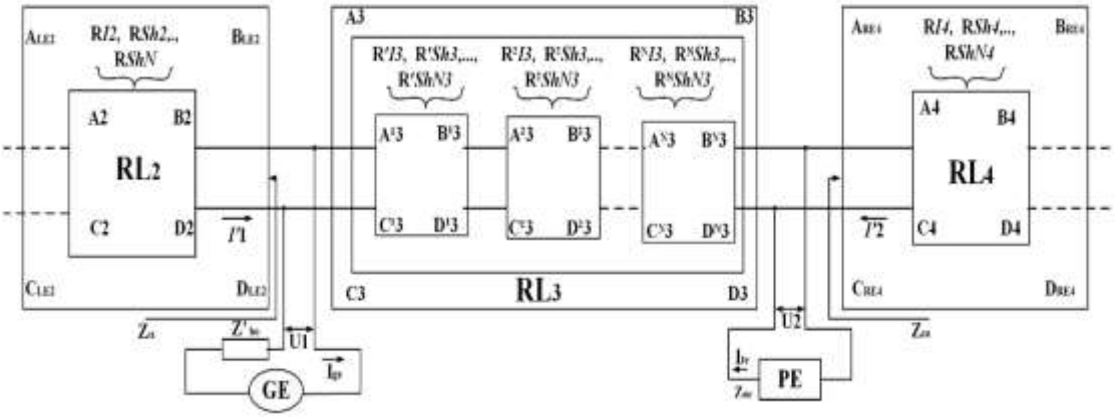

Figure 6. Calculated basic track circuit substitution scheme with discretely distributed parameters of rail lines

Voltages U1 and U2 and currents I1 and I2 at the ends of the rail line are related by the equations (Bryleev and Kotlyarenko, 1970):

$$U1 = A_E * U2 + B_E * I2;$$

$$I1 = C_E * U2 + D_E * I2. \qquad (8)$$

Calculation of voltages and currents of the ends of the RL3 rail line according to the basic equivalent circuit can be performed at any insulation resistance on each of the rail lines, any train coordinates, and any lengths of these trains. The algorithm for calculating the voltage of the receiving end and the current of the supply end is shown (Figure 7), 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 values of insulation resistances of each rail line, regulation coefficients fallouts precipitation (imitation of rain, indicating the location, intensity and time of precipitation), number and parameters of trains (values of resistances of shunts of cars, number of cars, speed of movement), module and argument of input resistances at the ends of the rail line, power supply voltage, scaling factors for outputting calculated curves, etc.;

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 first quadrupole (RL1) from the side of the power supply;

6.4 is calculation of the input resistance of the second quadripole (RL2) from the side of the power source;

6.5 is calculation of the input resistance of the fifth quadripole (RL5) from the side of the power supply;

6.6 is calculation of the input resistance of the fourth quadripole (RL4) from the side of the power supply;

6.7 is calculation of coefficients of a quadripole (RL3) taking into account the influence of adjacent rail lines;

6.8 is calculation of the power supply current (GE) and voltage at the receiver input (PE);

7 is calculation of the remaining track circuits;

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

9 is completion of work.

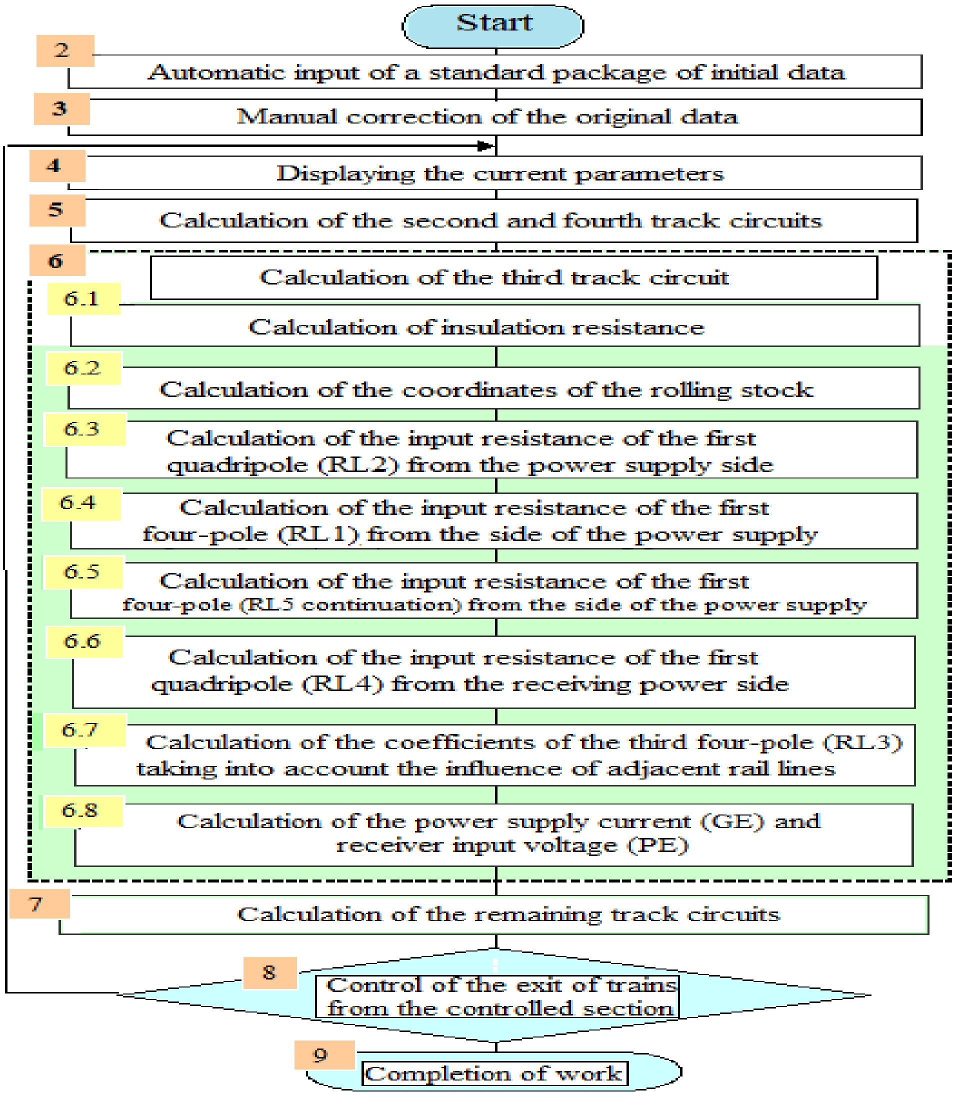

Figure 7. Algorithm of the program for calculating track circuits with discretely distributed parameters of rail lines

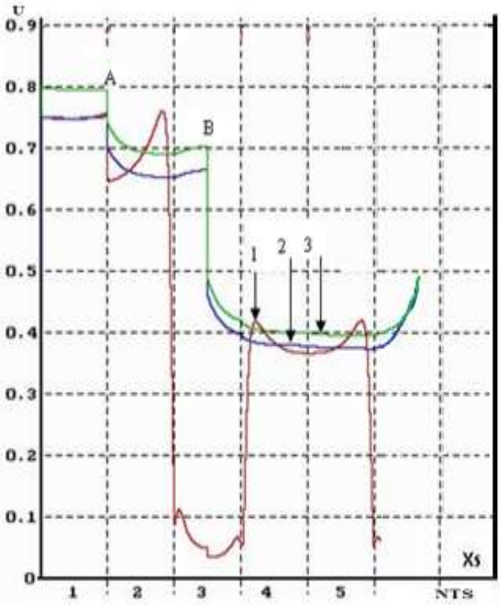

Figure 8. Graphs of stress dependences of the third track section from the coordinate of one standard shunts at dynamic change insulation resistance from 1om*km and below.

By figure 8 seen, that the change in the insulation resistance did not cause a violation of the reliability of monitoring of the track sections. Analysis of the operation of the track circuit on a computer showed, that the proposed method will allow monitoring the state of track sections even with a decrease in insulation resistance, which significantly increases the safety of train traffic.

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 circuit 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 subject of research 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 ends of the rail line.

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