Coordinated Track Circuits

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Abstract: The article considers a track circuit with an adaptive track receiver, which include coordinated track circuits that are part of correlative track circuits. This article describes a method for monitoring the condition of track sections by comparing the voltages at the inputs of track receivers of two rail lines. The described method can be used to monitor the condition of other rail lines.The main advantage and positive quality of the considered track circuits is that they have the ability to function with a small insulation resistance, have a much longer length and shunt sensitivity. In addition, these track circuits are susceptible to longitudinal asymmetry and to changes in insulation resistance, therefore they have a number of their own features according to the algorithm of their functioning and construction. The commissioning of coordinated track circuits increases the safety of train traffic, facilitates the working conditions of service personnel, as well as the reliability of the interval train traffic systems themselves.

1 INTRODUCTION

When analyzing the quality of the functioning of track circuits (TC), one of the main criteria is to ensure the safety of train traffic. The working conditions of the track circuits are far from normal, taking into account the number of destabilizing factors and interference from the traction network. The decisive factor in the evaluation is the degree (high) of noise immunity of the track receiver (TR). In order to remove or minimize the destabilizing factor affecting the operation of the TC, coordinated track circuits (TC) are proposed for use

Taking into account the main functional purpose of the TC, it is necessary to pay attention to the quality characteristic of the TR – noise immunity, which can be evaluated on the basis of the accepted elementary discrete symbols.

When researching new concepts or upgrading existing systems, experimental and analytical methods are used almost everywhere

In the vast majority of variants, the implementation of experimental research in conditions close to natural will require significant expenditure of both resources and time, and sometimes such a method is not possible at all. Of particular importance when evaluating the ITTS channels for noise immunity, where the communication line is track circuits (TC) and inductive rail lines (IRL), are studies conducted on the basis of reliable representations of both signals and interference.

It is used for some types of interference in RL, this is due to the fact that with one-time simultaneous recording of the values of the characteristics of interference and also absolutely all key conditions that have a great impact on them, there is a need for a special complex and expensive technique. In addition, in the event of an accident, it will be impossible to register interference.

Such disadvantages are absent when using analytical methods, but they can be used only if there is a probability to state mathematically quite clearly all the main conditions without exception that have a great influence in the procedure under study.

In these circumstances, one possible method of research is considered to be simulation modeling, implying the reconstruction of processes with the simulation of certain and random variables that have a direct impact on these processes.

2 MATERIALS AND METHODS

Methods based on the use of track circuits with adaptive track receivers (ATR) are considered to be one of the most promising ways to control the vacancy of the track. One of the types of adaptive

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track circuits is considered to be coordinated TC (CTC), which are part of the correlative track circuits (Akhmadulin, 2006; Akhmadulin, 2007; Akhmadulin, 2008; Akhmadulin, 2009; Akhmadulin, F. R., 2010; Akhmadulin, 2011; Akhmadulin, 2020; Polevoy, 2006). A significant positive quality of these TC is considered in this case, that they have the ability to function with a small insulation resistance, have a much longer length and shunt sensitivity. Together with this, such track circuits are susceptible to longitudinal asymmetry and how quickly changes in insulation resistance occur. The commissioning of such TC increases the safety of train traffic, improves the working conditions of service personnel, as well as the reliability of the interval train traffic systems.

The monitoring of the state of rail lines of track circuits is performed by analyzing the voltage at the input of the receiving end with a certain set value, constant for the entire service life.

Track circuits, in which two adjacent track circuits (TC) are used with one common track generator (TG), which is connected to the rail line at the boundary of their interfaces, are called coordinated track circuits (CTC). In such track circuits, detection and processing of signals at the output of the rail line is performed using difference approximation, in other words, by analyzing the received signal values and voltage values from the output of demodulators in track receivers.

The algorithm of operation of the coordinated track circuits (CTC) takes into account that during the normal operation of the TC, it is necessary to check two conditions when determining the vacancy/occupancy of the track section, including the rail breakage:

- -the magnitude of the voltages at the receiving ends of the track circuit must be the same;
- exceeding the voltage levels of the signals at the receiving ends of the TC of the voltage threshold of the sensitivity of the TR for the shunt mode of the TC.

This algorithm makes it possible to increase the stability of establishing the vacancy of the rail track, as well as the rail breakage in the event of a change in the insulation resistance of the rail line.

A special specificity of the recommended concept for the implementation of coordinated track circuits is the use of a microelectronic element base, which makes possible a relatively simple method (algorithm) of decision-making (Figure 1) on the vacancy/occupancy/breakage of the rail track in conditions of changing the values of the insulation resistance Z and the rail line.

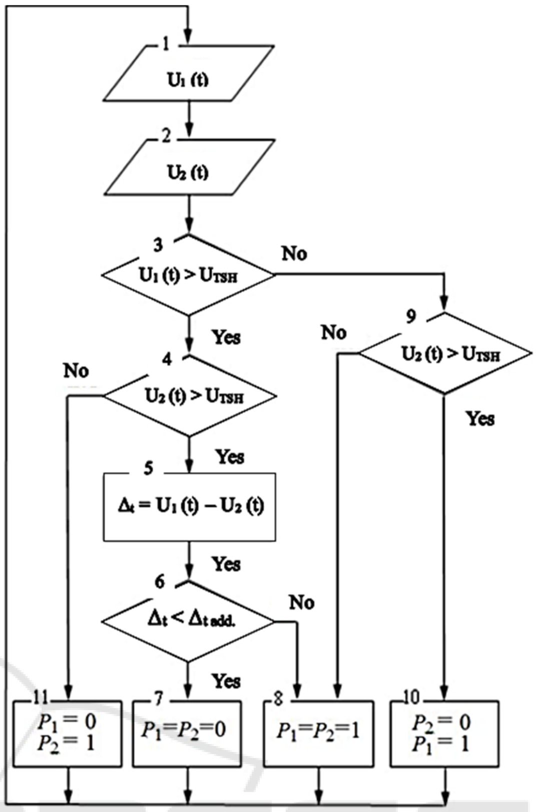

Figure 1: Diagram of the decision-making structure of the CTC.

Figure 1 shows the following values:

- the signal voltage at the output of the demodulators of the TR of the first and second coordinated TC, respectively, $U_1(t)$ and $U_2(t)$;
- the voltage of the shunt sensitivity threshold of the TR of coordinated TC U_{ST} (constant value);
- a value that takes into account the natural variation of $U_{1\ values}(t)$ and $U_2(t)$ under real operating conditions– Δ_t;
- the acceptable level of the value Δ_t. – Δ_{tACC}.

The conclusion about the possibility of the CTC operation over time and the change in the insulation resistance of the rail line is made taking into account the difference approximation:

1. A preliminary check of inequalities is being developed

$$U_1(t) > U_{ST}\ 0 \text{ and } U_2(t) > U_{ST};$$

2. The correspondence is calculated in time

$$\Delta_t = U_1(t) – U_2(t);$$

3. The value of Δ_t is compared with the established norms for a particular case with the value of Δ_{tACC}.

Let's define all existing combinations of values of these calculations:

1. There is a solution. $U_1(t) > U_{ST}$, $U_2(t) > U_{ST}$, $\Delta_t = U_1(t) - U_2(t)$ and $\Delta_t < \Delta_{t\,ACC}$– we are moving along the path 1-2-3-4-5-6-7.
2. There is a solution. $\Delta_t \geq \Delta_{t\,ACC}$ – we are moving along the path 1-2-3-4-5-6-8.
3. There is a solution. $U_1(t) > U_{ST}$, $U_2(t) \leq U_{ST}$ – we are moving along the path 1-2-3-4-11.
4. There is a solution. $U_1(t) \leq U_{ST}$, $U_2(t) > U_{ST}$ – we are moving along the path 1-2-3-9-10.
5. There is a solution. $U_1(t) \leq U_{ST}$, $U_2(t) \leq U_{ST}$ – we are moving along the path 1-2-3-9-8.

The algorithm presented in Figure 1 assumes the characteristic features of the functioning of coordinated TC with a single TG:

- analysis of voltage values of signals $U_1(t)$ and $U_2(t)$ in the TR demodulator of the coordinated TC exercising control of the 1st and 2nd adjacent rail sections of the track occurs in symbols 1 and 2;
- 3,4: comparison of voltage values $U_1(t)$ and $U_2(t)$ respectively with threshold values of sensitivity U_{ST} in TR shunt mode of the TC ($U_1(t) > U_{PS}$ and $U_2(t) > U_{PS}$) when exceeding $U_1(t)$ and $U_2(t)$ the values of U_{ST} are compared with the values of $U_1(t)$ and $U_2(t)$ between themselves by means of calculations according to the formula $\Delta_t = U_1(t) - U_2(t)$, and if $U_1(t)$ takes values greater than $U_{ST,}$ and $U_2(t)$ is greater than or equal to U_{ST}, then in the 11th character a decision is made that the second section of the rail track is occupied ($P_1 = 0$; $P_2 = 1$);
- symbol 6 is responsible for comparing the values of the values of Δ_t and $\Delta_{t\,ACC}$, necessary to fulfill the conditions when controlling the 7th and 8th symbols:
- -$\Delta_t < \Delta_{tACC}$ both sections of the track control are vacant ($P_1 = P_2 = 0$) (the decision is made in symbol 7);
- -$\Delta_t \geq \Delta_{tACC}$ both sections of the track control are occupied ($P_1 = 1$; $P_2 = 1$) (the decision is made in symbol 8);
- The symbols 8 and 10 are controlled by the symbol 9 in the case of:
- -$U_2(t) \leq U_{ST}$ both controlled sections of the track are occupied ($P_1 = 1$; $P_2 = 1$) (symbol 8)
- -$U_2(t) > U_{ST}$ the second of the controlled sections is vacant, the first is occupied.

An electrical functional circuit based on and implementing the algorithm (Figure 1) is shown in Figure 2.

The picture shows:

- rail lines under the control of the first and second sections of the track respectively – RL_1 and RL_2;
- rail lines adjacent to the controlled sections of the track – RL_{1-1} and RL_{2+1};
- protection and alarm devices – PAD;
- track generator – TG;
- track receivers of the first and second CTC respectively – TR_1 and TR_2;
- track receivers of TC adjacent to CTC – TR_{1-1} and TR_{2+1};
- decision-making device on the state of controlled sections of the track – DD_{1+2};
- devices for making decisions (decision devices) about the condition of the sections of the track adjacent to the CTC– $DD_{(1-2)+(1-1)}$ and $DD_{(2+1)+(2+2)}$.

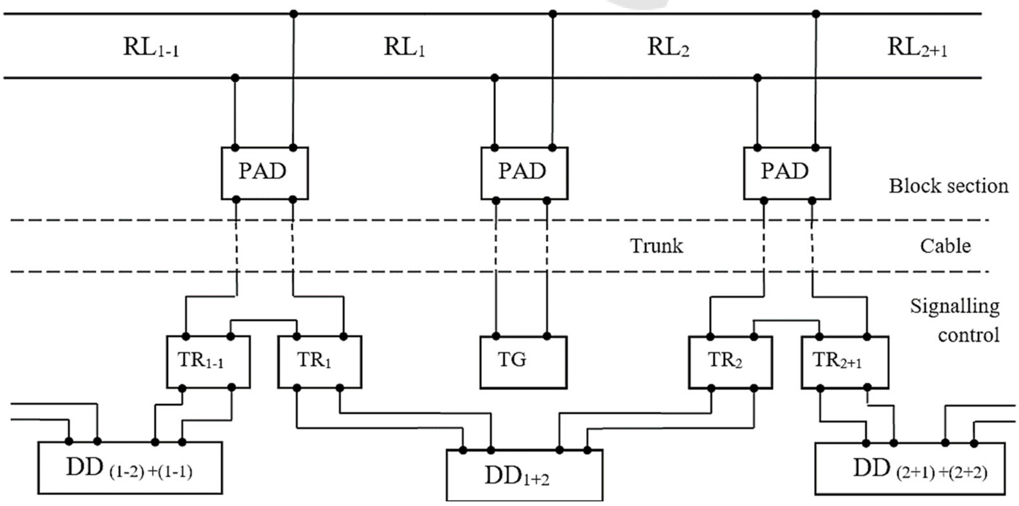

Figure 2: Electrical functional diagram of coordinated TC.

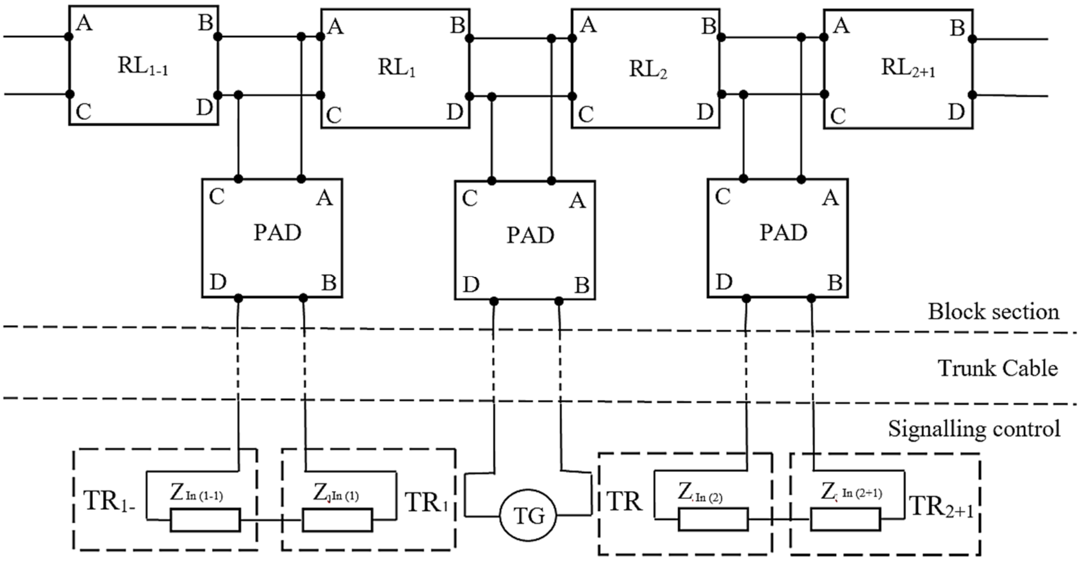

Figure 3: Replacement scheme of coordinated TC.

The device, which performs the control function when deciding on the state of the regulated sections of the rail-bed DD_{1+2}, works based on the algorithm, the block diagram is shown in Figure 1.

In accordance with the electrical functional scheme, which is shown in Figure 2, a single model of the replacement circuit for coordinated TC was compiled (Figure 3), taking into account the concepts of the theory of track circuits and the simulation apparatus, it is already possible to develop a simulation model of the coordinated TC.

3 CONCLUSIONS

Summing up, we can say that in order to establish and assess how effective the TC is, it is necessary to determine the ability of the track receiver to guarantee the reception and processing of signals with a set level of reliability under the worst operating conditions. In addition to this, the numerical coefficient for evaluating the efficiency of the system makes it possible to analyze the operation and functionality of the track circuit in different operating modes and with different inputs, as well as, if necessary, compare the TC with each other.

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