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CAUSES OF FAILURES IN THE TRACK CIRCUIT AND AUTOMATIC TRAIN CONTROL OPERATION

In the rail system is widespread the numerical coded circuit blocking and continuous automatic train control system. The system uses the frequency channel, organized on the rail line. Depending on the type of traction, the carrier wave frequency is equal to 25 or 50 Hz. As the element base the electromagnetic relays are used. In consequence of the low liability and safety, this system does not meet the requirements for the modern train separation arrangements. The number of failures and malfunctions of the numerical automatic block signalling and automatic train control system is large enough. Most of them are caused by unstable operation in the process of ballast resistance changing and interference of the traction current.

At the moment, the high-speed trains' traffic is rapidly developing. Therefore, the improvement of the interference resistance of the automatic train control system and reducing of the number of system failure is an important and unresolved issue.

The main causes of failures in the automatic train control system are shown in Figure 1.

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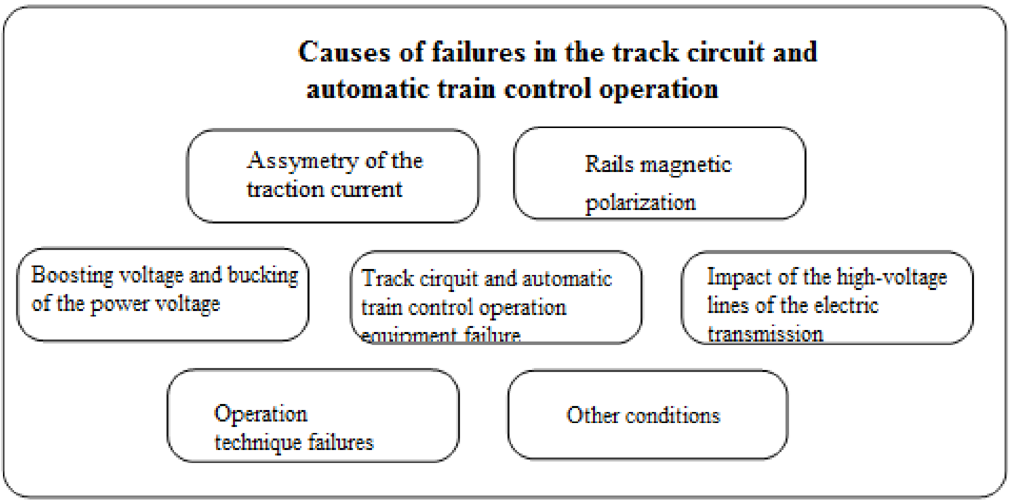

Figure 1. The main causes of failures in the track circuit and automatic train control operation.

Increased asymmetry of traction current - is a major cause of malfunctions of the Centralized Control Blocking devices. There are two types of traction current asymmetry, both types bring into existence the interference at the input of receiving devices of the track circuits and automatic train control system.

Series asymmetry is caused by different rail resistance to traction current, and is determined mainly by the state of butting connectors. To reduce the series asymmetry in accordance with the NTP SCB/MPS-99 design standards, track circuits are equipped with rail bonds on the railway hauls and ladder tracks. [1] The electrical resistance of the conductive joint should not exceed the resistance of the rail of the length of 6 meters (200 microohm). However, the resistance of the joint depends on the tightness of the track bolts, on the condition of the contacting surfaces, on the influence of the environment.

Scheme of the traction current flow in the double-rail track circuit with butting connectors is shown in Figure 2. Scheme is the same for direct and alternating traction current, code, phase-sensitive and tonal rail circuits, as well as for the devices of the automatic train control system.

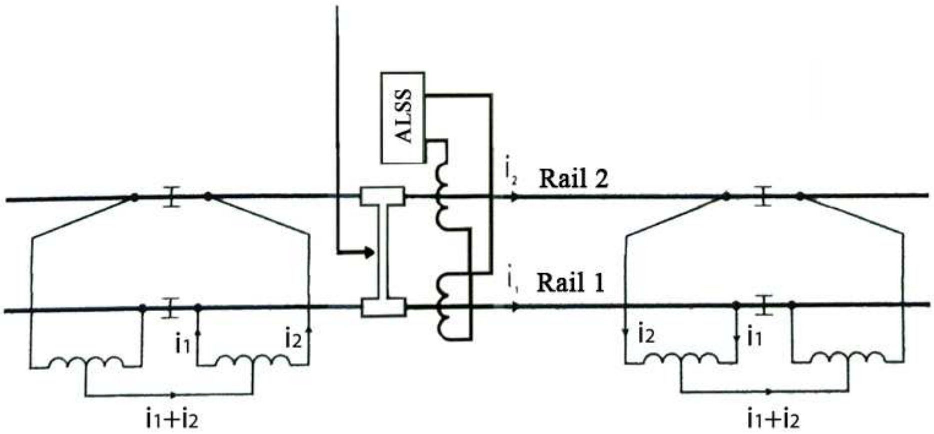

Figure 2. The scheme of the traction current flow

Series asymmetry in the track circuits can also occur because of differences in resistance of the short and long choke cables or because of the increased transient resistance in the fixturing point of the connector with the rail. It is possible to reduce the resistance of the long choke cable by replacing the connector with a large cross section or to use the connector of equal length.

The asymmetry coefficient $K = \left|\frac{i1 - i2}{i1 + i2}\right|$

Short track circuits are especially susceptible to the influence of asymmetry, which depends on the choke cables size. With the increasing length of the track circuit the series asymmetry is mainly determined by the resistance of the conductive joints. The most common interference in the transmitted signal occurs when the electric stock is on the segment before the short track circuit or directly on it.

On the continuous welded rail the size of the series asymmetry is much smaller and is determined only by the difference in resistance of the choke cables. In case of using the tonal rail circuits without block joints, the series asymmetry is practically absent.

Transverse asymmetry depends on the difference of the resistances of the insulation of rails relative to the ground. This type of asymmetry is a consequence of the conductive earth connection to the rails of the catenary supports, signal posts, bridges and other metal structures, located close to the tracks. For its limitation, in accordance with the Regulations for conductive earth of the electric supply devices on electrified railways [2], resistance to the marking current drain into the earth through the groundable construction to double-rail track circuit, should be at least 100 ohms. This requirement is not always fulfilled, what is one of the causes of the asymmetry currents. The values of the coefficients of the transverse asymmetry for the harmonic components 25, 50, 75 and 175 Hz and frequencies TRC-3 and TRC-4 under the normative devices content, should not exceed 4% at the resistance of the insulation rail line 1 ohm-km, and at 100 ohm-km - 11%. [2]

At the negative temperatures and frozen ballast, resistance of the rail line insulation increases, and the impact of the harmonic components of the traction current on the Centralized Control Blocking devices substantially increases due to the increased transverse asymmetry. Most influenced by traction current is the automatic train control system as there the traction current is always flowing in the rails under the locomotive traction coils, and any change of the differential traction current in the rails during the moving traffic immediately affects the level of interferences.

Impact on the automatic train control system devices is also determined by the differential current in the rails under the locomotive sending coils and in the places of the receiving apparatus connection of the track circuits.

Differential current $\Delta I = |i1 - i2|$

Differential current arises while movement of the locomotive along the catenary with the decreased resistance connected to the rail through the conductive earth. Variable height of the sending coils catenary of the Automatic Locomotive Signalling System, variation of electrical parameters, as well as fluctuations (vibration) during the movement cause an increase of the interferences level at the input of the train apparatus.

According to the Instructions on the protection of the rail underground structures from corrosion by the circulating currents [3], the asymmetry coefficient in the double-rail track circuits, in segments with constant traction current, should not exceed 6%. In segments with variable traction current it should not be above 4%. Currently, in segments with electric traction of the DC, the value of the return traction current in the rails should not exceed 120/0,06 = 2000 A, and at the electric traction of the AC -12/0,04 = 300 A. In actual practice, especially in segments with heavy and high-speed trains, the currents in the rails have larger values. For example, the return traction current of high-speed trains “Sapsan” in rails is up to 3000 and 320 A, under the electric traction of DC and AC, respectively.

There are always cases of spanning of the traffic lights before the starting electric stock, when starting traction current reaches the large value in close vicinity to the track circuit. It happens due to the fact that the asymmetry of the traction current leads to the DC magnetic bias of the magnetic frame of the impedance bond with secondary winding that causes a of the transformation coefficient and reduction of the useful signal at the input of the receiving apparatus of the track circuit. This may result in a false occupancy of the portion of line. In segments with electrical traction of AC the DC component appears under the regime switch of the traction engines operation and breach of contact between the current collector and the contact wire.

It is difficult to determine the value of the asymmetry under the electric traction of AC by the classical apparatus because of the several reasons. It is necessary to simultaneously record the indications of two apparatus, as well as being in close vicinity to passing trains. The value of asymmetry in the track circuits with electrical traction of DC is measured by the time consuming method according to the voltage in the rails after receding train.

Application of a Hall sensor for measurement of the current strength in the rails, jointly with the modern oscilloscope, as recorder of the asymmetry currents, allows to determine the value of the asymmetry current at any time and with any form of electric traction, and to perform hours-long recording of the return traction currents changes with subsequent analysis in computer. Measurements are made at a safe distance. Connection diagram is presented in Figure 3.

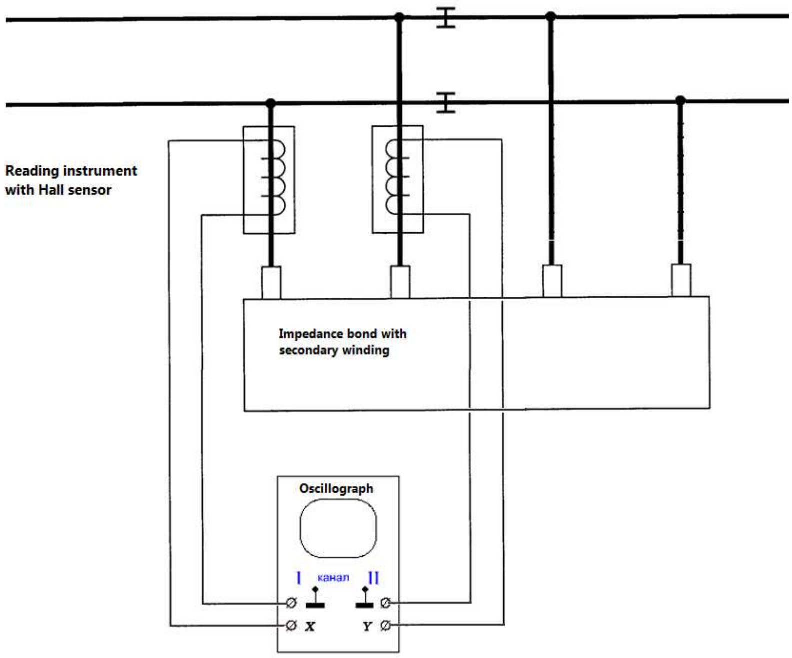

Figure 3. Connection diagram.

Impact on the equipment of the track circuits and Automatic Locomotive Signalling System depends on many random factors (the level of return traction current in the rails, regimes of the trains traffic and traction substations operation, the presence of other trains, etc.), so the faults and failures of the operation of the Centralized Control Blocking devices, under the increased asymmetry, may be variant, and its occurrence may depend on the change of an influencing factor. The impact of traction current and its harmonic components on the Centralized Control Blocking devices depends not only on the coefficient values of the rail line asymmetry, but also on the level of return traction current, flowing in the rails, and on the value of the differential current.

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[1] NTP SCB/MPS-99. The norms of epy process design of the automatic and teleautomatic devices and at the federal railway service
[2] Instructions on the conductive earth of the electric supply devices at the electrified railways.
[3] Instructions on the protection of railway underground structures from stray current corrosion.