Main electromagnetic jammer sources with impact on the railroad automation systems

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Abstract. The article presents some results of research to improve the stability of rail circuits and automatic cab signaling on the Railways. Signals of automatic locomotive signaling under the influence of stationary harmonic and random impulse noise are considered, the sources of which can be power lines, power devices, radio frequency electromagnetic fields, electrostatic discharges, lightning discharges, traction power supply and rail networks, as well as adjacent rail circuits. Particular attention is paid to the negative effects of reverse traction current and the uneven magnetization of the rails. It is shown that the practical implementation and application of the developed methods to increase the reliability of automatic locomotive signaling systems should suppress powerful interference from reverse traction currents that occur on locomotive receiving coils during heavy train traffic. Also, this should provide suppression of interference from the uneven magnetic field of the rails laid in the path or in the rut and at the ends of the sleepers. This will lead to a decrease in the intensity of failures in the operation of automatic locomotive signaling and to an increase in the level of safety and uninterrupted movement of trains. The results are successfully used on the railways of Russia and abroad.

1. Introduction

Automatic locomotive signaling systems are used to ensure automation of train traffic when following sections of railways. Therefore, the stability of the operation of ALS systems has a significant impact on the throughput capacity of railway sections and the district speed of trains needed to perform a given volume of traffic.

Track transmitting devices of ALS systems provide coding and transmission of information about indications of outdoor traffic lights and modes of a train to a locomotive cabin, while locomotive receiving devices are used to receive this information, de-encode it and output the corresponding indication to a locomotive traffic light and control the permissible speed in automatic mode. As a communication line, a rail line is used, inductively coupled to transmitting track and receiving locomotive equipment.

Signals of rail circuits (RC) and automatic cab signaling (ACS) are transmitted along rail lines, which are peculiar air communication lines exposed to the action of degradation processes, as well as
to the action of temperature; mechanical, electrical and electromagnetic effects, as a result of which the conditions of the flow along the lines of signal currents change.

Electromagnetic jammer sources to the apparatus of the RC and ACS can be power lines, power supply devices, radio-frequency electromagnetic fields, electrostatic discharges, lightning discharges, contact and rail networks of traction power supply, adjacent RC. In electrified sections of the Trans-Siberian railway the main source of interference is traction currents [1].

2. Interference source analysis

According to statistical data, the autonomous traction apparatus of ACS works 30 – 50 times more stable, and the apparatus of the RC works 6 – 7 times more stable than that with alternating current. When the electric direct current failures the work of ACS and the RC in average 4 to 5 times less than when the electric power of alternating current. This is determined by a lower level of interference from the direct current traction current and a narrower range of their harmonic composition.

Failures in the RC and/or ACS from the action of interference lead to false ceilings on the more forbidding the evidence of outdoor and/or cab of traffic lights. This reduces the throughput of railways and deteriorating traffic safety, especially in cases when there is a need to use emergency braking. Failures in the work of ACS also increase the psychophysiological load on locomotive crews.

At the request of the specialists of Vostochno-Sibirskaya Railway at the end of the last century in IrGUPS work on electromagnetic compatibility of systems of railway automation and telematics was started. The first result of these works was to ensure a successful and low-cost intermediate replacement of RC types without switching off the ACS during the transfer of electric power from a direct to a alternating current on the stretch Zima – Slyudyanka [2].

Preparation for the use of heavyweight traffic on the pass s stretch Irkutsk-Slyudyanka required clarification of the reasons for the lack of stability of the RC and ACS with alternating current. It was clear why the copper welded butt connectors with a cross section of 50 mm$^2$ was recommended by the normative documents for sites with such traction cause massive failure due to the unacceptable growth of their electrical resistance after 3 – 4 years of use instead of the required 7 – 8 years.

Studies in operational conditions and on a specially constructed stand showed that the main reason for this is the increase in resistance transitions between copper cables and steel tips in these connectors by electrochemical corrosion. Has been proven the ability to use connectors with flexible steel cable and manufacture such butt connectors. They have been used successfully on Vostochno-Sibirskaya Railway [3]. According to the results of these studies, such connectors are successfully used on European railways [4].

The process of generating interference on the track and cab receivers is multifactorial and very dynamic, as evidenced, for example, by the oscillograms recorded at station Polovina. Changes in the operating conditions of the traction motors of an electric locomotive approaching the station and simultaneous changes in the operating conditions of other electric locomotives in the zones between the traction substations significantly influenced the interference level and the degree of distortion of the sinusoidal curve of the signal voltage.

This is shown by recorded waveforms. In fig. 1, a one can see interference pulses with a frequency of 450 Hz, and in figure 6, b - a strongly distorted sinusoidal curve of signal due to the disturbing action of the first harmonic of the traction current.
3. Results and Discussion
During the movement of heavy trains at the stretch Bolshoi Lug - Slyudyanka, they were regularly falsely engaged in tone RC, which are most protected from interference. From the oscillogram in fig. 2 we can see that even in tone RC interference from an alternating traction, current can substantially distort the signal at the track receiver.

In some stretches of the Trans-Siberian Railways, equipped with reinforced concrete sleepers, in the summertime, false employment of the RC and increased intensity of ACS failures due to the deterioration of the electrical insulating elements of these sleepers were recorded. The method of diagnosing the state of electrically insulating gaskets installed under the rail lining was patented. The use of the method made it possible to reliably reject exploiting reinforced concrete sleepers [5].

The increase in traction current during the movement of heavy trains leads to an increase in the failure rate of ACS. Fig. 3 shows that, for example, the oscillogram of the voltage at the output of the cab filter ACS, recorded when the train was moving along the stretch Bolshoy Lug - Podkamennaya, in which due to a high level of interference a cab of traffic lights switched from green to white [6].
The intensity of failures in the indications of a cab traffic light on electric locomotives of different series at the same sections, under the same operating conditions, may differ several times. Studies have shown that the intensity of such failures in the operating conditions of traction was greater than in the operating conditions of recuperative, and with an increase in the weight of the train, this intensity increased [1]. The reasons for the difference in the level of interference at the input of the ACS locomotive receiver, generated by electrical equipment of electric locomotives of different series, are not yet clear.

Studies of the reasons for the unstable operation of ACS on the main route of the Krasnoyarskaya Railway after overhaul of the track revealed that this is due to interference from the uneven longitudinal magnetization of the newly laid rails and the magnetization of the ends of the changed rails when they are incorrectly placed inside the track or at the ends of the sleepers. As a result, effective measures were developed to exclude the effect of these factors on ACS [1, 7].

Measurements under exploiting conditions showed that the absolute value of the asymmetry of the traction current in a rail line was always greater than the asymmetry of the resistances of its rail threads. The failure rate increases when the ground freezes, and the asymmetry coefficient of the traction current varies inversely with its value in the rail line. The latter dependence is clearly seen from the results of research conducted at the Krasnoyarsk Railway (fig. 4).

The analysis of statistical data for a number of years on the Vostochno-Sibirskaya Railway and the Krasnoyarskaya Railway also showed that an increase in the ACS failure rate in November - December, that is characteristic, when freezing ground. Subsequent theoretical studies revealed that the appearance of the asymmetry of the resistance of rail threads is only the primary cause of the asymmetry of the traction current in it [8, 9, 10].

The value of the asymmetry of the traction current is significantly influenced by the mutual inductances of rail threads with other rail threads and with high-voltage power lines [11]. Due to the mutual inductance of the rail threads of the rail line, the asymmetry of the traction current can increase 2.5 times. Moreover, this dependence is more pronounced when the asymmetry coefficient of the traction current is close to its maximum permissible value [12].
After working on the preparation of floor devices for operation in winter conditions, an increase in the intensity of failures when negative ambient temperatures appear seems illogical. It was found that the reason for this is the dependence of the asymmetry coefficient of the traction current on the temperature of the rails [13].

Traction currents in the rails have a greater effect on the stability of the ACS receivers compared with the RC receivers. It is explained by two reasons. Firstly, the asymmetry of the traction current at the point where the RC is connected to the rails is determined by the difference in resistance of the rail threads along their entire length. The uneven distribution along the length of the rail line of increasing the electrical resistances of the elements of its rail threads leads to a certain degree of alignment of the total resistance of the threads and reduce the asymmetry of their values. Secondly, the resistance of the sections of the main windings of throttle transformer installed at the ends of the RC, play the role of ballast resistance, which also leads to a decrease in the asymmetry of the resistance of rail threads [13].

A complex of studies allowed developing a number of measures, the introduction of which, for example, in the crossing section through the Severobaikalsky mountain range, allowed the movements of heavy trains reduce to a certain extent the failure rate of ACS relative to the level that had been there before [14, 15, 16].

**4. Conclusion**

The situation on the main railways is changing relatively quickly, which necessitates the solution of new problems in the area under consideration. There is an intensive expansion of the use of high-speed traffic; the weight and intensity of the movement of heavy trains, including double ones, increase; new electric locomotives are used, the electromagnetic jammer from the traction current of which has a different harmonic composition; the use of expanded polystyrene expands the scope of use in the roadbed polystyrene and geotextiles with high electrical resistivity.

A simple linear extrapolation of known data to other operating conditions may be incorrect, since the processes of generating interference from alternating traction currents on the RC and ACS are non-linear.
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