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Features of the effect of increased reverse traction currents on rail circuits and continuous automatic locomotive signaling

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Abstract: The features of the influence of increased reverse traction currents on rail circuits and continuous automatic locomotive signaling are considered. It is shown that the current norms for the relative magnitude of the asymmetry of the traction current in the rail strands of the rail line were calculated for maximum reverse traction currents. When moving heavy-duty trains, especially in mountainous areas, reverse alternating traction currents can be significantly greater, so their effect on the ALS channels remains unclear.

Keywords: reverse alternating traction current, rail circuits, grounding resistances, choke transformer, reinforced concrete supports, track receivers of the DSSh-16 type

1. Introduction

As shown by the analysis of theoretical and experimental studies of electrical circuits with nonlinear choke transformers, inductors, their nonlinear properties are most strongly manifested at high currents flowing through their windings. At the same time, numerical data are known only for some points of the nonlinear dependence of the resistance of the main winding of choke transformers at variable traction magnetizing currents not exceeding the upper value of the permissible magnetization current.

The experience of running heavy trains on the road shows that up to three heavy trains can be on the stages at the same time with intervals of 12... 15 minutes between them. In this case, the greatest current load on the elements of the reverse traction network is obtained, as well as the greatest interference from the traction current on the RC and on the continuous automatic locomotive signaling (ALSN) devices. As a result, it has already been noted that the auto-lock signals overlap before the first train of the train pack. In such a train situation, the intensity of ALSN failures increases.

2. Methodology

Interference from the reverse traction current in the rails appears in the ALSN locomotive channel and in the equipment of the supply and relay ends of the RC with asymmetry of traction currents. The level of these interferences is directly proportional to the absolute value of the difference in traction currents in the rail lashes.

According to current standards, the relative value of this difference should be no more than 4% with the value of the reverse alternating traction current equal to 300A. The absolute value of the considered traction current difference should not exceed 15A [1,2,3]. The difference in traction currents in rail threads is directly proportional to the magnitude of the longitudinal and transverse asymmetry of the electrical resistance of the rail line and the magnitude of the traction current [4,5,6].

Longitudinal asymmetry of the resistance of the rail line RL) occurs when the resistances of the rail threads are unequal, when the sum of the resistances of the prefabricated conductive joints of the threads within the RC, limited by insulating joints or within the stretch with non-jointed RC, are not the same.

Transverse asymmetry appears when the resistance of the specified rail threads differs with respect to the ground. And if longitudinal asymmetry can be eliminated in principle, then transverse asymmetry on electrified sections of railways is always present where grounding circuits of contact network supports and other structures are connected to the right-hand rail thread on double-track sections [7,8,9,10,11,6].

The resistance of the outer rail thread with respect to the ground on electric traction runs is always less than such resistance of the inner rail thread. This is determined by the fact that grounding circuits of various structures located along the railway track are connected to the external rail.

The most widespread are the grounding circuits of the contact supports. To exclude the negative effect of these earths on the operation of RC and ALSN, their individual resistance is normalized at a level not lower than 100 ohms [12, 13].

The actual resistance of these circuits is usually lower for metal supports and structures, in which it varies between 0.5...200 ohms. On the railway network, about 40% of the considered earths have a resistance of up to 10 ohms, 70% – up to 20 ohms and over 90% – up to 50 ohms [14]. The grounding resistance depends on the size, structure and its type, depth of occurrence in the ground, type of foundation, degree of humidity and chemical composition of the soil, the service life of the structure.

Reinforced concrete supports have a grounding resistance (in the circuit between the console and the rail) in the range from 10 to 40,000 ohms, and about 40% of the supports have a resistance up to 1600 ohms [14]. The grounding resistance of reinforced concrete structures depends on the conductivity of concrete in the layer between the clamp and the reinforcement, the presence of electrical insulating coatings on the foundation and embedded parts.

3. Results

Artificial structures have the following limits of

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grounding resistance: bridges – 0.2...1000 ohms; overpasses – 0.15...40 ohms; pedestrian bridges and viaducts -0.4... 20 ohms. The grounding resistance of relay cabinets and traffic light masts is 20...30 ohms.

Metal supports of the contact network are used on a number of railway sections. An analysis of the numerical values of the resistance of their grounding circuits showed that the absolute majority of metal supports do not meet current requirements. These resistances usually do not exceed 30-40 ohms, the resistance of some supports does not exceed 5-10 ohms. Moreover, these supports stand on transshipment sites, where increased traction currents and the use of recovery significantly complicate the task of ensuring electromagnetic compatibility of ALSN devices with traction currents.

According to current requirements, structures with a ground circuit resistance below 100 ohms must be connected to the rail through spark gaps [12,13]. However, this requirement is not always fulfilled on the railway, which is one of the main reasons for the appearance of traction currents of asymmetry in rail threads, and therefore one of the main reasons for the insufficient stability of the ALSN operation. It remains unclear what is the degree of negative influence of grounding circuits with low resistance on the stability of the ALSN locomotive equipment.

On mountainous sections of the railway, cases of overlapping of entrance traffic lights at stations with traction substations and phase-sensitive RC with track receivers of the DSSh-16 type were recorded. One of the reasons for blocking the traffic light protecting a given route may be the false employment of one or more RC included in the route.

False employment with the serviceability of the RC equipment may occur when the protection devices of the RC equipment are triggered as a result of exposure to increased interference from the traction current. To protect the path receiver of a phase-sensitive RC with a DSSh-16 relay from traction current interference, a protective block filter of the ZB-DSSh type is used, consisting of a serial LC circuit tuned to the frequency of the first harmonic of the traction current, which is switched on in parallel with the track winding of the DSSH16 relay. Thus, harmonics of the traction current can enter the input of the track winding of the DSSh-16 relay, which in turn can reduce the amount of torque of its sector. This may be the reason for the false release of the relay sector.

The dependence of the magnetic flux in the core of the DT-1-150 and DT-1-300 type choke transformers on the current flowing through the main winding is nonlinear, which determines the nonlinearity of their characteristics.This non-linearity is confirmed by the manufacturer. When magnetizing choke transformers of these types, manufactured before 1995, with a voltage of 5 V with a frequency of 50 Hz applied to the main winding, the total resistance of the main winding to alternating current with a frequency of 25 Hz and a voltage of 4 V on the main winding increases by 40% (from 0.5 to 0.7 ohms) [2, 6].

For the choke transformers DT-1-150 and DT- 1-300, manufactured after 1995, the same total resistance of the main winding at a voltage of 4 V with a frequency of 25 Hz is obtained when it is magnetized by an alternating current of 50 Hz with a power of 4 A (across the entire winding), that is, at a voltage of 4 V.

The manufacturer does not explain why new modifications of throttle transformers have become more sensitive to the magnetization of their cores by alternating current of industrial frequency.

The total resistance of the main winding of the choke transformers of the specified type, in the absence of magnetization, should be equal to 0.5 ohms at a frequency of 25 Hz at a voltage of 0.3 V at a frequency of 25 Hz, that is, it is measured in a different mode. The resistance of the main winding to direct current at a temperature of + 200 should be no more than (3.5 ± 0.35) mOhm of the latest modifications of types DT-1-150 and 2DT-1-150, and for choke transformers of types DT-1-300 and 2DT-1-300 no more than (1.6±0.16) mOhm.

Magnetization of the core of a choke transformer by direct current leads to a decrease in the resistance of its main winding [15]. The resistance of the main winding of the choke transformer is halved at a constant magnetization current of 2A, which corresponds to a magnetization voltage of 7 mV applied to the entire winding.

4. Discussion

In the absence of core magnetization and a sinusoidal voltage between the terminals of the coil, the magnetic flux in the core is also sinusoidal and does not depend on the properties of the ferromagnetic material. In the presence of core saturation, the sinusoidal magnetic flux contains, first of all, a significant third harmonic component [15].If the magnetizing current remains sinusoidal, the non-sinusoidal trapezoidal shape is assumed by the magnetic flux. Consequently, a nonlinear choke transformer, when it is magnetized, becomes a generator of higher voltage harmonics in its windings.

The nonlinear characteristic of the choke transformer is symmetrical. If a voltage is applied to such an element in the form of two components K, the frequencies of which are correlated as 1:2, then in the current passing through the choke transformer, despite the absence of rectifiers, a constant component equal to K. Such a fact of the occurrence of a constant component in the conditions under consideration is called selective rectification [15]. Selective rectification is called because it occurs not at any frequency ratios of two voltages, but at a well-defined one.

The appearance of a constant component in the current flowing through the main winding of the choke transformer causes the appearance of even harmonics of sinusoidal currents flowing through this winding. The phase of even harmonics depends on the sign of the constant component [17].

Thus, the non-linearity of the characteristics of choke transformers of types DT-1-150, 2DT-1-150, DT-1-300 and 2DT-1-300 leads to the appearance of harmonics of traction current and signal frequency in rail circuits, and selective rectification causes the appearance of direct current, which additionally magnetizes the core of choke transformers.

The signal current of the ALSN with a frequency of 25 Hz at the beginning of a 2.5 km long code stage rail circuit varies from 5,l to 16 A, and in station phase–sensitive rail circuits with a frequency of 25 Hz with a 1.2 km long DCSH relay - in the range from 2.3 to 7 A, that is, these currents have the same order as and traction currents of asymmetry in the main windings of the choke transformer [18]. Since frequency converters are powered from phase C, and voltage is supplied to the contact network from phase A or B, there is always a phase shift between the signal and traction voltage in the main winding of the choke transformer[19]. Consequently, choke transformers have all the necessary conditions for the appearance of selectively rectified current in their main windings.

5. Conclusion

Measurements in rail circuits with a frequency of 25 Hz on electrified sections of the railway confirmed the appearance in some cases of a constant voltage component on the main winding of the DT-1-150 choke transformers, reaching a value of 0.005 V. Consequently, the constant magnetizing current at the same time exceeded 1.4 A, which leads to a decrease in the resistance of the main winding of the choke transformer by about 40%.

Thus, the magnetization of the core of the choke transformer by traction currents of industrial frequency asymmetry while simultaneously applying a signal current with a frequency of 25 Hz to it causes an increase in the resistance of the main winding. As a result of selective rectification, a constant component appears in the current of the main winding, which in turn causes the appearance of even harmonics of sinusoidal currents passing through the winding. These harmonics also cause selective rectification of currents, although the DC current that appears in this case will have a smaller value due to the fact that the amplitude of the harmonics is less than the amplitude of the signals of the main frequencies of 25 and 50 Hz.

Thus, the current norms for the relative magnitude of the asymmetry of the traction current in the rail strands of the rail line were calculated for maximum reverse traction currents of 300 A. This asymmetry determines the requirements for the longitudinal and transverse asymmetry of rail lines, as well as for the characteristics of nonlinear elements in the RC and ALSN equipment. When moving heavy-duty trains, especially in mountainous areas, reverse alternating traction currents can be significantly greater, so their effect on the ALS channels remains unclear.

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