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IMPACT OF ELECTROMAGNETIC PHENOMENA ON AUTOMATICS, TELEMECHANICS AND TRAFFIC CONTROL SYSTEMS IN DC AND AC CONTACT NETWORK'S POWER SUPPLY JOINT STATIONS

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Abstract. The article examines technical problems emerging in connection of railway sections with different contact network powering systems, and methods for their solution are relevant when connecting electrified railways of separate countries into common Trans-European corridors. The article presents practical and theoretical aspects and methods of solution for technical issues related to DC- and AC-electrified railway line joints. It provides theoretical calculations and test data evidencing impact of various systems on automatics, telemechanics and traffic control systems. For determination of factors influencing traffic control and signalling systems, the authors performed tests allowing to prove that, especially in winter periods, direct traction currents, when 'rail-ground' electric resistance increases significantly, reach a distant AC-electrified section and influence the traffic control and signalling system installed therein, namely generate interference endangering traffic safety.

Keywords: catenary, AC-DC catenary supply system, substation, joint stations.

1. Introduction

A in most countries of the world, railways are electrified using different power-supply systems for contact network. In many countries, the contact network power-supply system has direct current (DC), with voltages of 750 V, 1500 V, 3 000 V. The system was installed for electrification of railways up to the mid 20th century. Later railways were electrified using alternating current (AC), using power-supply standards of 15 kV, 16,75 Hz and 25 kV, 50 Hz. Thus different railway electrification systems can exist in a single country. In the European Union, all the abovementioned systems are operated. When connecting railways into common networks, it is necessary to solve their compatibility problems.

Lithuanian railways, electrified with AC 25 kV, 50 Hz power-supply system, will have to be connected to Polish, Latvian, and Kaliningrad Region railways, electrified with DC 3 000 V contact network voltage system. Ukraine, aiming at integration into EU, will have to adjust different power-supply systems for contact network. Connection of different contact network power-supply systems in various states extends lengths of sections, thus allowing operation of fast electric trains, with speed ranging up to 300 km/h and more.

2. Traffic control and signalling systems

Various automated block systems are used for traffic control. To create a circuit for traction current among electric locomotive, electric train and traction substation, rails are used. The rails are also used for automatic control of light signals and for transfer of coded signals to locomotive. Track circuits are made for this purpose. Example of track circuit installation is shown in Fig. 1.

Railway tracks, being a conductor, are used to create not only the traction current circuit, but also the circuit of signalling current of automatic blocking tracks, and therefore various schemes exist for achievement of these goals. Schemes of possible use of track network are shown in Fig. 2.

3. Problems of compatibility of different contact network power-supply systems

In DC and AC contact network, power-supply systems can be coordinated with the help of three methods: 1. By inserting between railway sections electrified with different systems a section where diesel locomotives can operate pulling passenger cars, or diesel trains; 2. By using electric locomotives and electric trains with a few power-supply systems (such

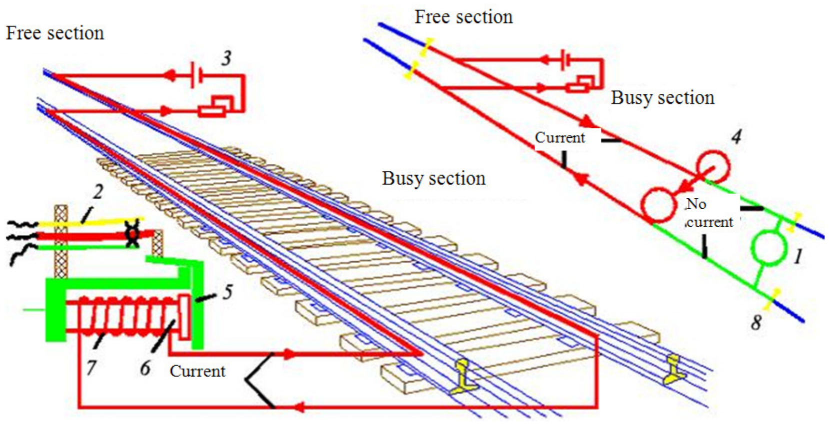

Fig. 1. Track circuit:
1 – Track block relay; 2 – Relay contacts; 3 – Accumulator battery; 4 – Wheel pair; 5 – Relay anchor; 6 – Core of electromagnetic relay (magnetic circuit); 7 – Coil windings; 8 – Insulated joints

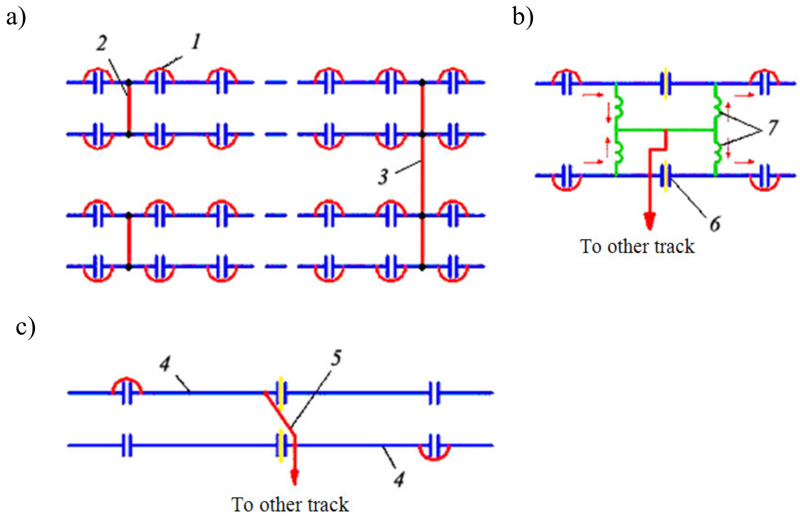

Fig. 2. Track network:
a) – Tracks used only for traction current circuit; b) – Tracks used for traction current and signalling current circuit; c) – Tracks used for traction current and signalling current circuit; using a single rail;
1 – Inter-rail electric connection; 2, 3 – Inter-track electric connections; 4 – Traction current rail; 5 – Transverse electric connection; 6 – Insulated joint; 7 – Throttle transformer

as EuroStar fast electric trains running between Paris and London over the English Channel, which are adapted for AC 25 kV, 50 Hz, 15 kV, 16,75 Hz and DC 750 V contact network power-supply systems) or by installing DC and AC contact network power-supply joint stations.

The article examines a specific DC-3 000 V and AC-25 kV, 50 Hz contact network power-supply joint station and impact of different systems on automatic blocking systems used for traffic control. The impact can result in interference that could influence operation of light signals, i.e. it can prevent assurance of traffic safety. In DC electrified sections, track circuits use coded signals of 50 Hz. In AC electrified sections, the track circuits use 25 Hz and 75 Hz coded signals. Moreover, in AC electrified sections, for transfer of signal current and returning traction current to substation, throttle transformers of lesser power DT-1-150 are used. This is so because returning traction current to substation is significantly lower in AC electrified sections.

Because of asymmetry of electric parameters in rails, exceeding normative requirements [1], in DC system the direct traction current reaches the AC system's throttle transformers DT-1-150 and saturate their magnetic circuits with direct current, thereby distorting the traffic control and signalling system. This phenomenon is especially strong in winter, when disconnecting separate electricity consumers of common DC-AC traction substation as installed in joint station.

4. Experimental and theoretical justification of reasons of electromagnetic phenomena

Experimental tests were carried out in railway station of two contact networks' power-supply systems AC-DC junction. Scheme of a railway section with AC-DC contact network power-supply system is shown in Fig. 3.

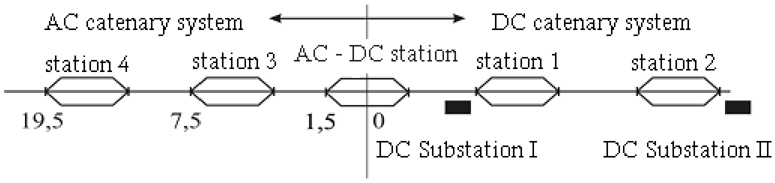

Fig. 3. Scheme of railway section with AC- DC contact network power-supply system

In order to assess distribution of currents and potentials on railway line at nominal load modes of traction substations and forced disconnections of separate substations, currents of substations *Substation II* and *Substation I* were measured. Currents of traction substations when both substations operate are shown in Table 1.

Table 1. Currents of traction substations when both substations operate

Substation	*Substation I*	*Substation II*
current I, (A-busbar)	*488A*	*1834A*

Value of current in traction *substation's II* busbar A, at forced mode, with *Substation I* disconnected, is shown in Table 2.

Table 2. Value of current of traction s*ubstation's II* busbar A, with s*ubstation I* disconnected

Substation	*Substation II*
current I, (A-busbar)	*2170A*

Currents and potentials in track circuits were measured and recorded with the help of special devices for measuring and registration of electric parameters TEAC R–71, M–231, analogue-digital transducer and computer. Direct current was measured using M–231 device, connected to current-measurement bypass 100 A–75 mV; alternating current was measures using a hook-on meter. Characteristic moment of measurement of track potentials is shown when disconnecting *DC Substation I* in Fig. 4 and Fig. 5.

Fig. 4 shows 'rail-ground' potential as measured in western part of AC-DC railway station. Fig. 5 shows spectral analysis of the potential. Maximum value of direct current potential was found as 10,1 V, and maximum value of 50 Hz frequency potential – as 6,5 V.

Distribution of direct current in AC-electrified sections was calculated by making a mathematical module with the help of microelectronic computing machine ESM. The calculations were made assuming that traction substations work in normal mode and with traction DC Substation I disconnected, using instantaneous schemes. Output data for calculation of traction substation parameters were obtained by performing measurements in *DC Substation I and DC Substation II (see Tables 1 and 2)*.

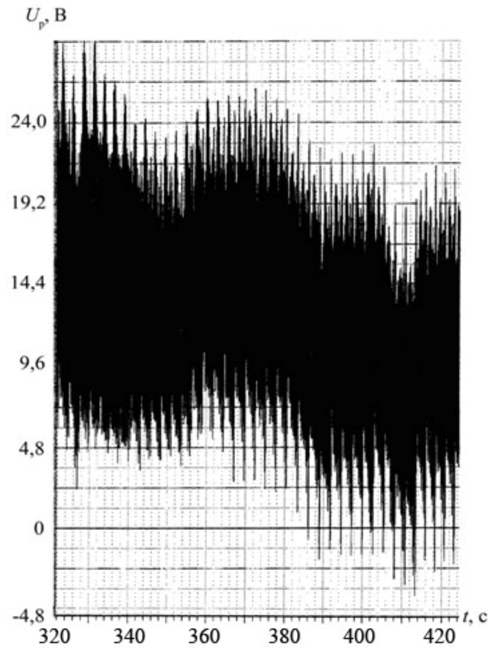

Fig. 4. 'Rail-ground' potential as measured in western part of AC- DC railway station

Normal mode of DC substation I and DC substation II. For normal mode of the substations, the calculation scheme as shown in Fig. 6 was made.

Let's enter equation of traction substations track network for the calculated zone 1 (AC-electrified section):

$$I_{px} = \frac{1}{2} \cdot \left(I_{01} \cdot e^{-6 \cdot (3-x)} - I_1 \cdot e^{k \cdot x} - \right.$$
$$\left. - I_2 \cdot e^{-k \cdot (20-x)} + I_{02} \cdot e^{-k \cdot (27-x)}\right), \quad (1)$$

where x – coordinate of given zone; I_{01} – *DC Substation I average daily current*, A; I_{02} – *DC Substation II average daily current*, A; k – track network coefficient. [2]:

$$k = \sqrt{\frac{r_p}{r_n}} \quad (2)$$

Where r_p – comparative transverse track network resistance ohm/km; r_n – comparative transient resistance between rail and ground.

Ohm·km

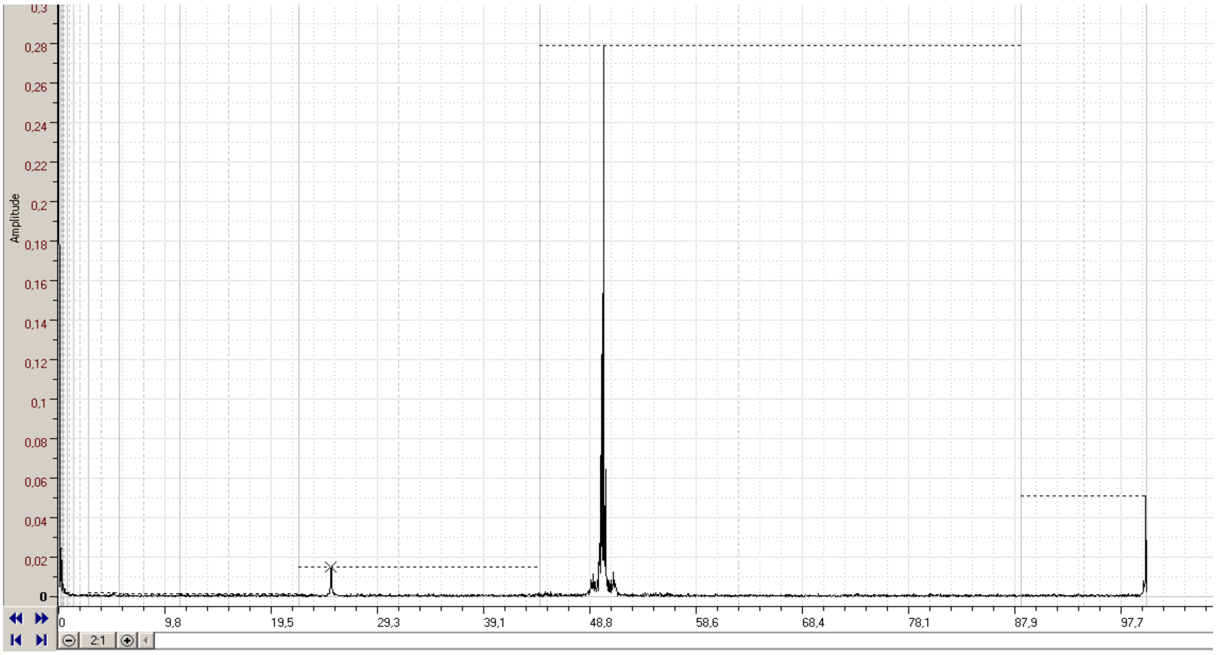

Fig. 5. Spectral analysis of 'rail-ground' potential

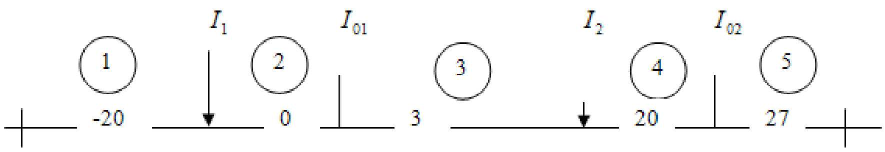

Fig. 6. Calculation scheme for normal mode of DC substation I and DC substation II

Summary of calculation results is shown in Table 3.

Table 3. Values of currents in rails at normal mode of traction substations

X, km	I_{px}, A	
	r_i = 0,25 Ω·km (spring-autumn)	r_i = 10 Ω·km (winter)
–25	–0,103	–31,087
–21	–0,279	–36,335
–19,5	–0,404	–38,524
–18,5	–0,518	–40,056
–17,5	–0,664	–41,649
–12,5	–2,294	–50,616
–7,5	–7,928	–61,515
–6,5	–10,16	–63,961
–5,5	–13,019	–66,505
–3,5	–21,379	–71,9
–1,5	–35,108	–77,733
0	–50,929	–82,416

Forced operation mode of traction substations (with DC substation I disconnected). The calculation scheme is analogous to that of normal mode. It must be assumed, however, that the disconnected substation's current I_{01} will be zero. Calculation results are shown in Table 4.

Table 4. Values of currents in rails, with *substation I* disconnected

X, km	I_{px}, A	
	r_i = 0,25 Ω·km (spring-autumn)	r_i = 10 Ω·km (winter)
–25	–0,338	–80,849
–21	–0,912	–94,499
–19,5	–1,322	–100,192
–18,5	–1,695	–104,177
–17,5	–2,172	–108,32
–12,5	–7,504	–131,642
–7,5	–25,932	–159,986
–6,5	–33,23	–166,349
–5,5	–42,583	–172,965
–3,5	–69,928	–186,996
–1,5	–114,831	–202,166
0	–166,578	–214,345

5. Conclusions

The practical measurements performed and the calculation results prove that direct traction currents can intervene deeply into AC-electrified track network and, in case of asymmetry of track circuit (transversely and longitudinally), they can magnetise magnetic circuits of throttle transformers DT-1-150 and, at the same time, evoke faults of railway signalling system, able to interfere with railway traffic safety system.

To ensure reliable operation of railway signalling system in AC-DC joint stations, AC-electrified sections, the authors suggest the following:

1. When designing joint (connecting) railway stations of different contact network standards AC-DC, the impact upon traffic control and signalling systems should be adequately taken into account.

2. In order to reduce the impact of direct traction current on AC-electrified section, preventive works in DC traction substations including full disconnection should be performed in spring-autumn seasons, when transient 'rail-ground' resistance is lower.

3. In order to reduce corrosion of reinforced-concrete supports and structures in AC-electrified section of 8 km from AC-DC joint station [3], supports of contact network should be earthed individually, also spark inserts, diode earthing electrodes etc. should be installed.

4. In order to reduce impact of direct traction current upon AC-electrified section, zero points of throttle transformers should not be interconnected, especially at the end of joint station tracks. In this case short circuits of traction circuit, provoked by high currents in this mode, can result in hazardous potentials in insulated joint of tracks and cause interference [4].

5. It is necessary to create new normative documents and technical requirements and to correct existing ones:

– In respect of traction current asymmetry for throttle transformers;

– In respect of permissible levels of contact network support earthing resistances for signalling and traction current.

– In respect of leakage norms of signalling and traction current to ground over earthing of contact network supports [5].

6. All these measures as suggested by authors will allow saving public funds and assuring traffic safety in joint stations.

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