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Vladimir GAVRILYUK[1]
Alexandr ZAVGORODNIJ[2]

THE MODELLING OF ELECTROMAGNETIC INFLUENCE OF TRACTION ELECTROSUPPLY SYSTEM ON RAILWAY CIRCUITS

The mathematical model described of electromagnetic influence of AC traction railway electrosupply on functioning of adjacent DC railway circuits for two parallel railway lines with a various types of electrsupply is obtained. The model takes into account inductive influence of a current in a contact wire and leakage of the current into the ground. The calculations of rail potentials and return traction current in rails are carried out according model.

MODELOWANIE WPŁYWU ELEKTROMAGNETYCZNEGO SYSTEMU SIECI TRAKCYJNYCH NA OBWODY TOROWE

Uzyskano matematyczny model opisujący wpływ elektromagnetyczny kolejowej sieci trakcyjnej AC na funkcjonowanie pobliskich obwodów kolejowych DC dla dwóch równoległych linii kolejowych o różnych typach trakcji elektrycznej. Model bierze pod uwagę wpływy elektromagnetyczne prądu w pantografie i upływy prądu do ziemi. Obliczenie potencjałów szynowych i powrotnego prądu trakcyjnego w szynach zostało przeprowadzone zgodnie z modelem.

1. INTRODUCTION

New types of a rolling stock with pulse converters and computer systems for regulation of theirs movement developed last time has made especially actual a problem of electromagnetic compatibility of traction electrsupply system (TES) with railway automatics. When high-speed railways with AC electrsupply (25 kV) will be developed at railways sites with traditionally existing DC electrsupply (3 kV), it will be possible simultaneous functioning of two railway lines with various type electrosupply.

[1] Department of Automatic and Telecommunications, Dnepropetrovsk National University of Railway Transport, Lazaryana 2, 49010 Dnepropetrovks, Ukraine, E-mail: gvi_dp@mail.ru
[2] Main Engineer of State Enterprise "Pridniprovsk Railway".

Therefore research of electromagnetic influence of AC traction railway electrosupply on functioning of adjacent DC railway circuits for two parallel railway lines with a various types of electrosupply is practically important.

2. THE PURPOSE OF THE WORK

The purpose of the present work is development of mathematical model described of electromagnetic influence of AC traction railway electrsupply on functioning of adjacent DC railway circuits for two parallel railway lines with a various types of electrsupply.

3. MATHEMATICAL MODEL

The traction railway electrsupply system consists of a contact wire, the messenger wire strengthening wire (in some electrsupply system), and two rails connected with the ground by small impedance. The voltage in a contact wire induces electrostatic potential in rails (electric influence), the alternating current induces a longitudinal electromoutive force (EMF) in rails (electromagnetic influence). The return traction current flowing in rail line renders influence on automatic devices. A part of traction current flows down from rails into the ground and renders conductometric influence on work of the next track circuits. For the adequate description of electromagnetic processes in railway traction electrsupply system the equivalent multiwire long lines circuit used (Fig. 1) [1,2]. Zero line on fig. 1 corresponds to conductivity of the ground, 1, 2 - lines correspond rail lines with potentials relative ground *U1, U2*, and a line 3 corresponds to conductivity of contact wire with potential *U3*. Complex admittances between rail lines and partial conductivity between each rail and the ground are designated as Y_{12}, Y_{10}, Y_{20}. Mutual inductance between lines i and j are designated as M_{ij}. Differential equations for voltage U_i and currents I_i $(i=0..\ 3)$ are written as [1,2]

$$\frac{d\dot{U}_1}{dx} = Z_{11}\dot{I}_1 + Z_{12}\dot{I}_2 - Z_{13}\dot{I}_3 \tag{1}$$

$$\frac{d\dot{U}_2}{dx} = Z_{21}\dot{I}_1 + Z_{22}\dot{I}_2 - Z_{23}\dot{I}_3 \tag{2}$$

$$\frac{d\dot{U}_3}{dx} = Z_{31}\dot{I}_1 + Z_{32}\dot{I}_2 - Z_{33}\dot{I}_3 \tag{3}$$

$$\frac{d\dot{I}_1}{dx} = -Y_{11}\dot{U}_1 + Y_{12}\dot{U}_2 \tag{4}$$

$$\frac{d\dot{I}_2}{dx} = Y_{21}\dot{U}_1 - Y_{22}\dot{U}_2 \tag{5}$$

Where $Z_{11} = R_1 + jX_{L1}$, $Z_{22} = R_2 + jX_{L2}$, $\underline{Z}_{31} = R_3 + jX_{13}$, $Y_{11} = Y_{12} + Y_1$, $Y_{11} = Y_{22} + Y_2$.

The electromagnetic influence of a signal current in rails on a current in a contact wire was neglected in this equations. For a two parallel railways the differential equations was written similarly

$$\frac{d\bar{\dot{U}}}{dx} = |\underline{Z}|\bar{\dot{I}} \tag{6}$$

$$\frac{d\bar{\dot{I}}}{dx} = |\underline{Y}|\bar{\dot{U}} \tag{7}$$

where $\bar{\dot{U}}, \bar{\dot{I}}$ - are vectors of voltage and current in wires, $|\underline{Z}|, |\underline{Y}|$ - are matrixes of mutual resistances and admittances Z_{ij}, Y_{ij}. Values of active and inductive resistance of a rail lines for traction and signal currents are given in the literature [1,2]. It is possible to use L. Nejman's formulas that give satisfactory coincidence with experimental data [1,2]

$$R = \frac{l}{u}\sqrt{\mu_e \rho \omega}, \qquad X_l = 0.6\frac{l}{u}\sqrt{\mu_e \rho \omega} \tag{8}$$

where l - length of a conductor, u - perimeter of its section, ρ - a resistivity of steel, $\omega=2\pi f$ - a circular frequency, μ - a magnetic permeability of rail steel. The impedance of a rail line with length 1 km can be determined with formula

$$Z_{ii} = (r_i + r_c) + X_i \tag{9}$$

in which r_i, X_i - accordingly, active and a reactive resistance of a rail line with a length 1 km, r_c - resistance of rail splices (on 1 km of a rail line). The mutual inductance between two rails, and also between a rail and a contact wire may be determined according known formula [1,2]

$$M_{ij} = 10^{-4}\left[1 + 2\ln\frac{2}{1.78(a-r)\sqrt{4\pi\sigma\omega}} - j\frac{\pi}{2}\right],$$

in which a is a distance between wires, r – equivalent wire radius, σ - conductance of the ground.

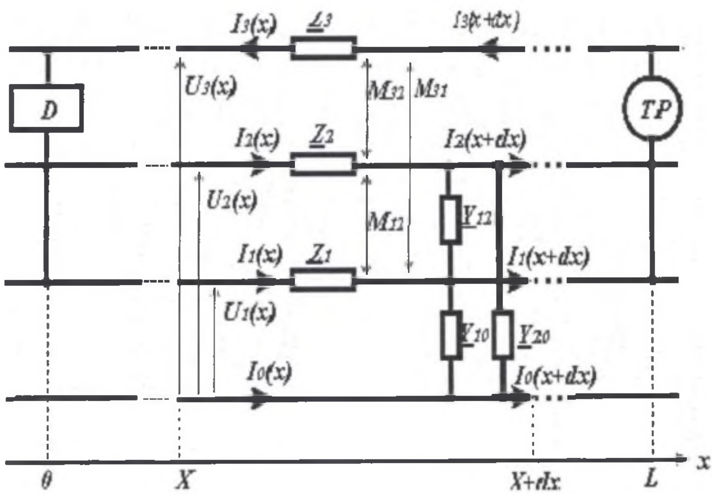

Fig.1. The equivalent circuit of railway traction electrsupply system

Let's enter the coefficients describing asymmetry of a rail line

$$K_i = \frac{I_1 - I_2}{I_1 + I_2} = \frac{I_1 - I_2}{2I}, \tag{10}$$

$$K_u = \frac{U_1 - U_2}{U_1 + U_2} = \frac{U_1 - U_2}{2U}, \tag{11}$$

$$K_z = \frac{Z_1 - Z_2}{Z_1 + Z_2} = \frac{Z_1 - Z_2}{2Z}, \tag{12}$$

$$K_Y = \frac{Y_1 - Y_2}{Y_1 + Y_2} = \frac{Y_1 - Y_2}{2Y}. \tag{13}$$

Let's transform (1) - (5) with the account (10) - (13)

$$\frac{d\dot{U}}{dx} = -\underline{Z}_0\dot{I} + \underline{Z}_M\dot{I}_3, \tag{14}$$

$$\frac{d\dot{I}}{dx} = -\underline{Y}_0\dot{U}, \tag{15}$$

where $Z_0 = (1 - K_I K_Z)Z$, $Y_0 = (1 + K_U K_Y)Y$. The equations (14), (15) have known decisions

$$U(x) = C_1 e^{\gamma x} + C_2 e^{-\gamma x}, \tag{16}$$

$$I(x) = -\frac{1}{Z_c}\left[C_1 e^{\gamma x} - C_2 e^{-\gamma x}\right] + mI_3, \text{ where } m = \frac{Z_{31}}{Z_1 + Z_{21}}. \tag{17}$$

Constants of integration C_1 and C_2 are defined from boundary conditions at $x=0$ and $x=L$. For resistance of a ballast insulation lower 1 Ohm/km expressions for integration constants are simpler

$$C_1 = \frac{1}{2}(m-1)Z_c I_3, \tag{18}$$

$$C_1 = \frac{1}{2}(m-1)Z_c I_3 \tag{19}$$

4. RESULTS AND DISCUSSION

The numerical modeling of tractive current flowing in rail lines was provided according obtained results. The dependences of a voltage on a rail line from relative coordinate $x=X/L$ for three values of a leakage conductance are given in Fig.2, and dependence of a current value in a rail line from coordinate $x=X/L$ at various values of a traction current flowing in a contact wire of other railway and at various values of a leakage conductance between rails and ground are given in Fig.3.

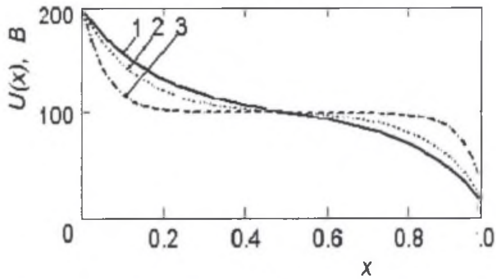

Fig. 2. The dependences of a voltage on a rail line from relative coordinate $=X/L$ for three values of a leakage conductance $Y_1=Y_2$ (Sm / km): 5 (1), (2), 1.5 (3)

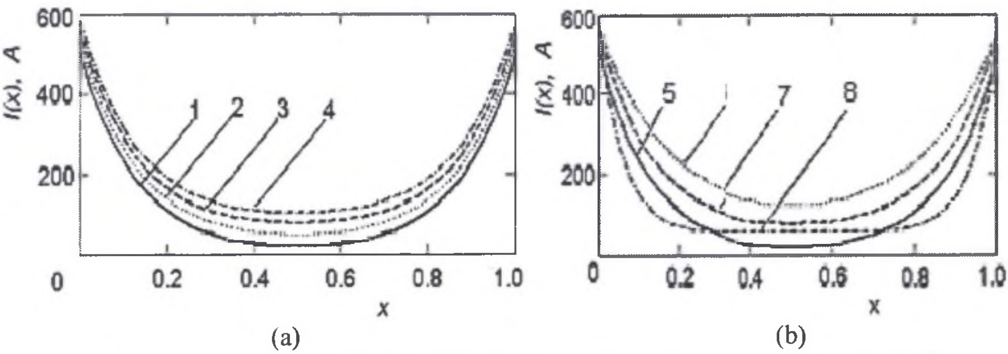

Fig. 3. The dependence of a current value in a rail line from coordinate $x=X/L$ atvarious values of a traction current flowing in a contact wire of other railway: 0 (1), 50 A (2), 100 A(3), 150 A (4) and at various values of a leakage conductance between rails and ground $Y_1=Y_2$ (Sm / kn) 5 (5, 6), 1.0 (7), 0.5 (8)

It is possible to see from Fig.2, 3 that voltage in rail lines decreased strongly with increasing distance from locomotive to traction supply station and a current in rail lines obtained minimum value in the middle of the distance between locomotive and station. The character of these curves depends on an insulation resistance between rails and ground that explained by current leakage from rails to ground. As can be seen from Fig.3(a) the current values in rail lines with DC traction electrosupply are dependent on the current value in adjacent railways with AC traction electrosupply, that explained by inductive influence AC rail lines on DC rail lines. The induced current have frequency 50 Hz (as a frequency of signal current in DC railways circuits) and difference between induced currents in two rail lines is about value of a signal current. coincides with frequency of signal current. So alternating current flowing in contact wire one railway induced current in adjacent DC railway circuits that comparable with signal current and as a result may caused preventing or dangerous influence on functioning of railway automatic devices.

5. CONCLUSION

The mathematical model described of electromagnetic influence of AC traction railway electrsupply on functioning of adjacent DC railway circuits for two parallel railway lines with a various types of electrsupply is obtained. The model takes into account inductive influence of a current in a contact wire and leakage of the current into the ground. The calculations of rail potentials and return traction current in rails are carried out according model.

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Reviewer: Ph. D. Andrzej Białoń