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MATHEMATICAL MODELS OF ELECTROMAGNETIC EFFECTS OF THE TRACTION SYSTEM ON THE ADJACENT LINES

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Abstract:

In the article, mathematical models of the electric and magnetic effects of the traction system under tension on the approach lines are developed, taking into account the reverse effect of the approach line. Also, the current and voltage values generated in the adjacent line in different modes of the adjacent line were analyzed and it was determined that the most dangerous voltage generated in the adjacent line due to the electric effect of the affected line is generated in the first mode, and the most dangerous voltage generated due to the magnetic effect is generated in the second mode.

Keywords: traction system, adjacent line, electric and magnetic effect, mathematical model, induced voltage, elementary section.

The traction system for power supply devices (supply and suction conductors, contact network conductor and rail) itself is the main influence chain. Since the traction system is symmetrical, it has a very high electromagnetic effect compared to the adjacent lines that are switched off or in operation.

In the existing literature, mathematical models have been developed by considering the closed circuit between the contact line and the ground without taking into account certain boundary conditions, i.e., the rail effect, and considering the approach of the contact line and the adjacent line as mutually parallel. The introduction of these boundary conditions leads to an erroneous estimation of the electromagnetic influence of the traction system on the adjacent lines. Also, reducing the value of the induced voltage in the adjacent lines causes difficulties in the development of measures .

For a more complete mathematical analysis of the electromagnetic effects of the traction system in relation to the adjacent lines, we construct a scheme of mutual approximation of the contact line and the adjacent line. In this case, the reverse effect of the adjacent line is also taken into account, and the currents and voltages in the affected line are assumed to be constant along the line.

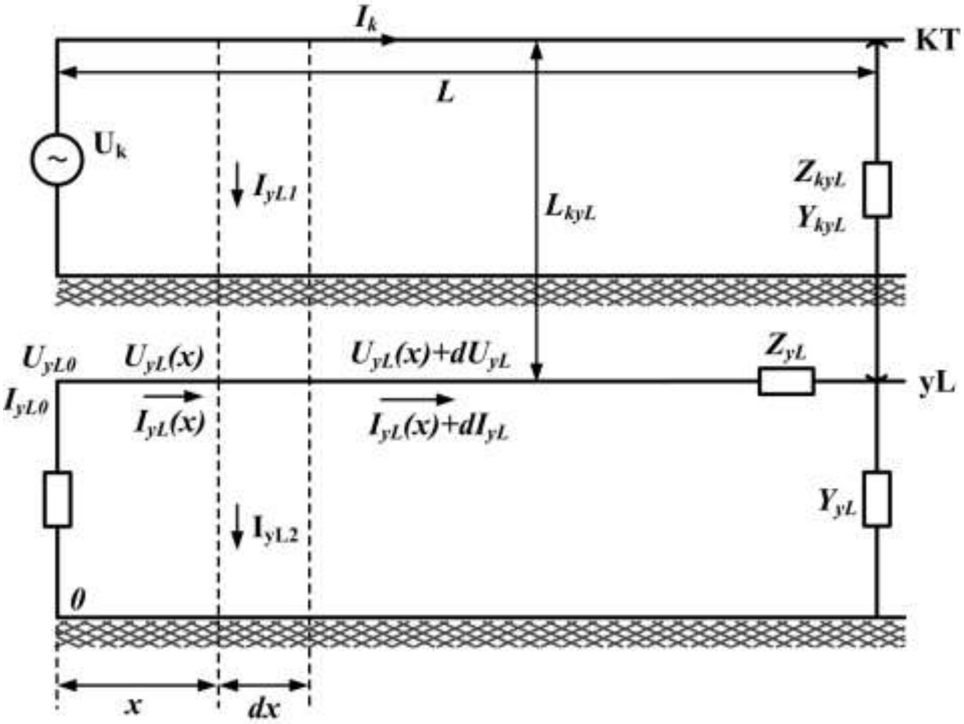

Fig. 1. Approach scheme of contact lines and adjacent line

The following equation is valid for the elementary section of the adjacent line:

$$-dU_{yL}(x) = Z_{yL}I_{yL}(x)dx + Z_{kyL}I_k dx \qquad (1)$$

here $Z_{yL} = r_{yL} + j\omega L_{yL}$- total resistance of the adjacent line corresponding to one km., Ohm/km; r_{yL}- active resistance of the adjacent line; ω– angular frequency; L_{yL}– the inductance of the adjacent line; $Z_{kyL} = j\omega M_{kyL}$– mutual induction resistance corresponding to one kilometer between the contact line and the adjacent line, Ohm/km; M_{kyL}– the mutual induction coefficient between the contact line and the adjacent line; $U_{yL}(x)$– the voltage generated in the adjacent line due to the induced voltage of the contact line ; $I_{yL}(x)$– the current generated in the adjacent line due to the induced voltage of the contact line; U_k, I_k– induced voltage and current of the contact line, respectively.

Since there are two unknowns in expression 1, it is necessary to construct the second differential equation.

For this, the following equation is relevant for the current in the elementary section:

$$dI_{yL}(x) = I_{yL1} - I_{yL2} = \left(U_k - U_{yL}(x)\right)Y_{kyL}dx - U_{yL}(x)Y_{yL}dx,$$

$$-dI_{yL}(x) = \left(U_{yL}(x) - U_k\right)Y_{kyL}dx + U_{yL}(x)Y_{yL}dx \qquad (2)$$

here $I_{yL1} = \left(U_k - U_{yL}(x)\right)Y_{kyL}dx$- the current that can flow from the contact network to the adjacent line, $Y_{kyL} = G_{kyL} + j\omega C_{kyL}$- the mutual conductivity between the contact line and the adjacent line, G_{kyL}- the active conductivity, C_{kyL}- the capacity between the contact line and the adjacent line; $I_{yL2} = (U_k - U_{yer}(x))Y_{yL}dx$– the current that can flow from the adjacent line to the ground, $U_{Yer}(x) = 0$– ground potential, $Y_{yL} = G_{yL} + j\omega C_{yL}$, G_{yl}– active conductivity (insulation conductivity) between the adjacent line and the ground, ωC_{yL}– reactive (capacitive) conductivity between the adjacent line and the ground.

$U_k \gg U_{yL}(x)$since the inequality holds, $U_{yL}(x)$we can ignore the parentheses in expression 2. According to expressions 1 and 2, the following equations are valid:

$$-\frac{dU_{yL}(x)}{dx} = Z_{kyL}I_k + Z_{yL}I_{yL}(x),$$

$$-\frac{dI_{yL}(x)}{dx} = -Y_{kyL}U_k + Y_{yL}U_{yL}(x).$$

By differentiating these equations, we create the following second-order differential equations:

$$\frac{d^2U_{yL}(x)}{dx^2} = \gamma^2 U_{yL}(x) + Y_{kyL}Z_{yL}U_k = 0 \qquad (3)$$

where $\gamma = \sqrt{Z_{yL}Y_{yL}}$ is the wave propagation coefficient in the adjacent line.

We know that the solution of this second-order linear non-homogeneous equation is:

$$U_{yL}(x) = A_1e^{\gamma x} + A_2e^{-\gamma x} + A_3, \qquad (4)$$

where are A_1, A_2, A_3 the integration constants to be determined.

Taking the double derivative of expression 4 and substituting expression 4 into expression 3, we get the following result for the adjacent line voltage:

$$U_{yL}(x) = A_1e^{\gamma x} + A_2e^{-\gamma x} + p_2U_k \qquad (5)$$

here $p_2 = \frac{Y_{kyl}}{Y_{yL}}$.

Adjacent line voltage for determined sequence like of the adjacent line current the solution too is determined and it is below in appearance will be :

$$I_{yL}(x) = -\frac{1}{Z_{yLT}}(A_1 e^{\gamma x} - A_2 e^{-\gamma x}) - p_1 I_k \qquad (6)$$

here $Z_{yLT} = \sqrt{\frac{Z_{yL}}{Y_{yL}}}$– wave resistance of the adjacent line; $p_1 = \frac{Z_{kyL}}{Z_{yL}}$. and current I_{yL0} at A_1 the beginning of the adjacent line U_{yL0} and A_2 the constants of integration. For this, we use the following boundary conditions:

$$x = 0, U_{yL}(x) = U_{yL0},\ I_{yL}(x) = I_{yL0}.$$

This borderline conditions 5 and 6 - expressions to put through integration constants for the following to the results have we will be :

$$A_1 = \frac{U_{yL0} - p_2 U_k}{2} - \frac{Z_{yLT}(I_{yL0} + p_1 I_k)}{2}$$
$$A_2 = \frac{U_{yL0} - p_2 U_k}{2} + \frac{Z_{yLT}(I_{yL0} + p_1 I_k)}{2}$$

A_1 and putting A_2 the constants of integration into expressions 5 and 6, we get the following resulting mathematical expressions for the adjacent line voltage and current:

$$U_{yL}(x) = (U_{yL0} - p_2 U_k) ch\gamma x - Z_{yLT}(I_{yL0} + p_1 I_k) sh\gamma x + p_2 U_k, \qquad (7)$$
$$I_{yL}(x) = -\frac{U_{yL0} - p_2 U_k}{Z_{yLT}} sh\gamma x + \left(I_{yL0} + p_1 I_k\right) ch\gamma x - p_1 I_k. \qquad (8)$$

and currents I_{yL0} at the head of the adjacent line in the developed mathematical expressions U_{yL0} can be determined based on its operating mode (the head of the line is isolated from the ground $\dot{I}_{yL0} = 0$ or the head of the line is grounded $\dot{U}_{yL0} = 0$) and with the help of these expressions it is possible to determine the values of the voltages and currents in the adjacent lines located within the electromagnetic influence of the contact line.

The current and voltage generated by the electric and magnetic effects on the side line depend on whether the side line is insulated or grounded. Let's consider the currents and voltages that occur in the adjacent lines in three different modes:

- the adjacent line is isolated from the ground, the current at the beginning and end of the wire is zero;
- the head of the adjacent line conductor is insulated, the end is grounded using a very small resistance grounder, the current at the beginning of the wire is zero, and the voltage at the end of the wire is zero;
- the head and end of the adjacent line conductor are grounded, the voltage at the end and the beginning of the wire is zero.

The standard values of the currents and voltages generated in the adjacent lines due to the electric and magnetic effects of the traction system using expressions of the mathematical model developed according to the relevant conditions for the section under investigation and draw appropriate graphs using the resulting expressions.

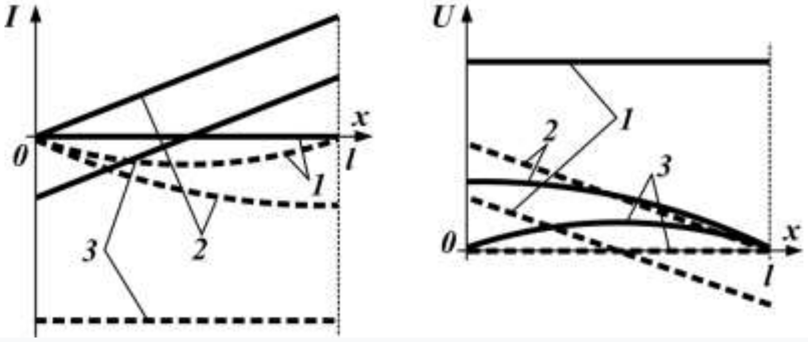

Fig. 2. Currents and voltages generated in the adjacent lines due to the electric (continuous line) and magnetic (dotted line) effects of the traction system

On the basis of the mathematical model of the investigated section traction system, as a result of researching the standards of current and voltages in the adjacent line, it was determined that the most dangerous voltage that occurs in the adjacent line due to the electric effect of the affected line is generated in the first mode, and the most dangerous voltage that occurs due to the magnetic effect is generated in the second mode. It is appropriate to take into account the results of this research in order to ensure the safety of workers serving the adjacent lines under the influence of the traction system under tension.

REFERENCES

1. Amirov S.F., Boltayev O.T., Akhmedova F.A. Calculation of Magnetic Chains with Mobile Screens // International Journal of Advanced Research in Science Engineering and Technology. India. - №6, Issue 5, May 2019 - pp. 9243-9245.

2. Sulton, B. Otabek, A. Firuza. New created mathematical models of movable screens and a scatter parameter converters //(Scopus) Jour of Adv Research in Dynamical & Control Systems, Vol. 12, Special Issue-02, 2020. pp. 122-126.
3. Amirov S. F., Boltayev O. T. Mathematical models of differential magnetic circuits of converters with movable screens and distributed parameters //Journal of Tashkent Institute of Railway Engineers. – 2019. – Т. 15. – №. 3. – С. 75-81.
4. Boltayev O.T., Akhmedova F., Kurbanov I. Consideration Of The Nonlinearity Of The Magnetization Curve In The Calculation Of Magnetic Chains With A Moving Electromagnetic Screen. Universum: технические науки 2-7 (95) (2022): 68-71.
5. Boltaev O.T., Akhmedova F.A, & Nafasov N.O. (2021). Analysis Of Moving Electromagnetic Screen Devices. Texas Journal of Multidisciplinary Studies, 3, 188–192.
6. Boltayev O.T. and Akhmedova F.A. Induced Voltage From Traction Networks and Methods of Reducing its Influence on Adjacent Communication Lines. International Journal on Integrated Education. 4, 4 (Apr. 2021), 265-271.
7. Boltayev O.T., Bayanov I.N., Akhmedova F.A. Galvanic effects of the gravitational network and measures to protect against it. International journal of trends in computer science ISSN:2348-5205. Volume 2, Issue 1, 2021. pp. 3-11.
8. Амиров С. Ф., Болтаев О.Т. Исследование магнитных цепей новых преобразователей усилий //Автоматизация. Современные технологии. – 2020. – Т. 74. – №. 1. – С. 24-26.
9. Amirov S.F., Boltayev O.T., Ataullayev A.O. Matematicheskiye modeli elektricheskogo polya aktivnoy zoni elektromagnitnogo datchika rasxoda s kolsevim kanalom //Molodoy ucheniy. – 2020. – №. 29. – S. 32-36.
10. Boltayev O.T., Mirasadov M.J., Nurxonov B.SH. Issledovaniye staticheskogo rejima magnitnix sepey s podvijnimi elektromagnitnimi ekranami i s raspredelennimi parametrami // Universum: texnicheskiye nauki. 2021. №5-5 (86).