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MODELING AND EXPERIMENTAL STUDIES OF LEAKAGE CURRENTS AND CURRENTS SPREADING ON THE ELEMENTS OF A HIGH-VOLTAGE SUPPORT

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ABSTRACT

Traditionally in Kazakhstan electricity over long distances passed overhead high-voltage power lines with a voltage of 220 - 500 kV.

High-voltage power lines are strategic for the electricity system in Kazakhstan and the damage caused by their significant accidents.

In use the elements of a design of support located underground contact to various environments: soil, water, air; besides, are affected by the currents wandering in soil induced by current carrying elements. Therefore there is an effect of electrochemical corrosion which is described in the form of the equations of electrochemical reactions.

This presentation does not allow the process to identify the effects of specific factors galvanic corrosion for concrete structures supports.

As you know, one of the major causes of electrochemical corrosion is the nature and magnitude of the leakage currents on the support member and the current spreading in the soil caused by the induced electromagnetic fields.

Developed a universal mathematical model based on the methods of theoretical foundations of electrical engineering and Kirchhoff laws.

This model allows us to describe the nature and magnitude of the leakage current on all elements of support; interaction leakage currents and currents spreading in the soil support member located below ground; identify the most vulnerable elements of support, subject to galvanic corrosion; develop

recommendations for redesign of support to minimize leakage currents and losses.

A similar model can be developed for any design support.

There were also conducted experimental studies to confirm the effectiveness of the model.

INTRODUCTION

One of the major causes of electrochemical corrosion is the character and magnitude of leakage currents on the elements of pillar and current spreading in the soil caused by the induced electromagnetic fields.

Analyzed the work of M.I. Mihailov, L.D. Razumov., S.A. Sokolov [1,2,5] on the influence of high voltage lines to underground pipelines and facilities of communication, as well as the corrosion of metals exposed to alternating currents.

Similarly analyzed works M.A. Tolstaya, E.I. Ioffy, I.V. Potemkinskaya about the impact of the AC power frequency on electrocorrosion steel and ways of combating it [3,4].

In the work of A.A. Zakharov, V.V. Popov, S.V. Nikolashkin provides principles for the development of mathematical models and recommendations for the safe operation of 110 kV at the site "Yakutsk-Churapcha-Khandyga" [6].

In paper Marin D., Palii L., Samoilescu G., Nicolaie S., Nedelcu A., Ilie C., Popa M. A theoretical model and the program on the numerical determination of the electromagnetic and thermal phenomena on power lines [7].

The analysis did not reveal the presence of models describing the effect of leakage currents and spreading to the structural elements of high-voltage power lines.

MATHEMATICAL MODELING OF HIGH-VOLTAGE SUPPORT

Mathematical model was developed to support high-type PB-500 [8].

Description of the model produced by the methods of the theoretical foundations of electrical engineering [9,10].

Figure 1 shows the equivalent circuit [11] of the type of support PB - 500, combined with the image of the tower structure.

For the considered application is the most suitable method of loop currents [7,8]. In the generalized model, made on the basis of this method is simple enough to implement its decomposition into elementary contours distribution of leakage currents and elements of support and current spreading in the soil that provides the visibility of the model.

This model does not include all the air resistance of the circuit, derived from the phase because of their large sizes.

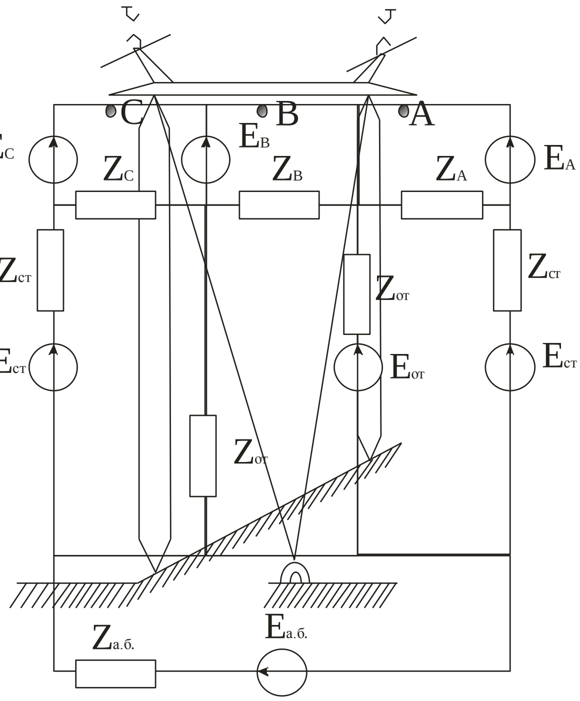

Fig. 1. The approximate equivalent circuit pillar PB-500

Thus, we obtain the equivalent circuit of the pillar (Figure 2).

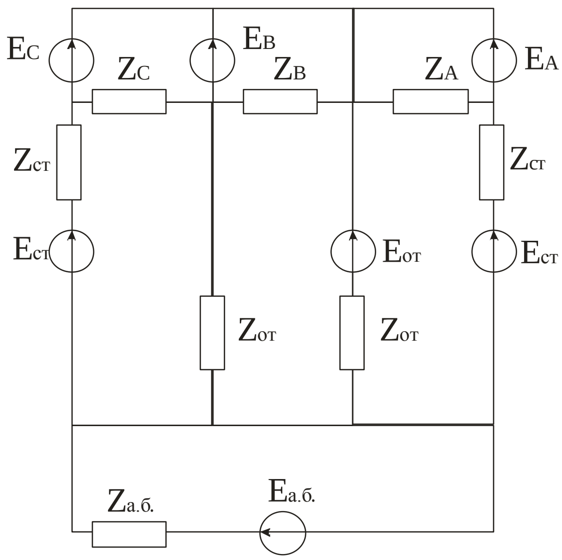

Fig. 2. Equivalent circuit pillar PB-500

Arbitrarily we arrange directions of the currents in the circuit branches, take the direction of bypass circuits, denoted nodes (Figure 3).

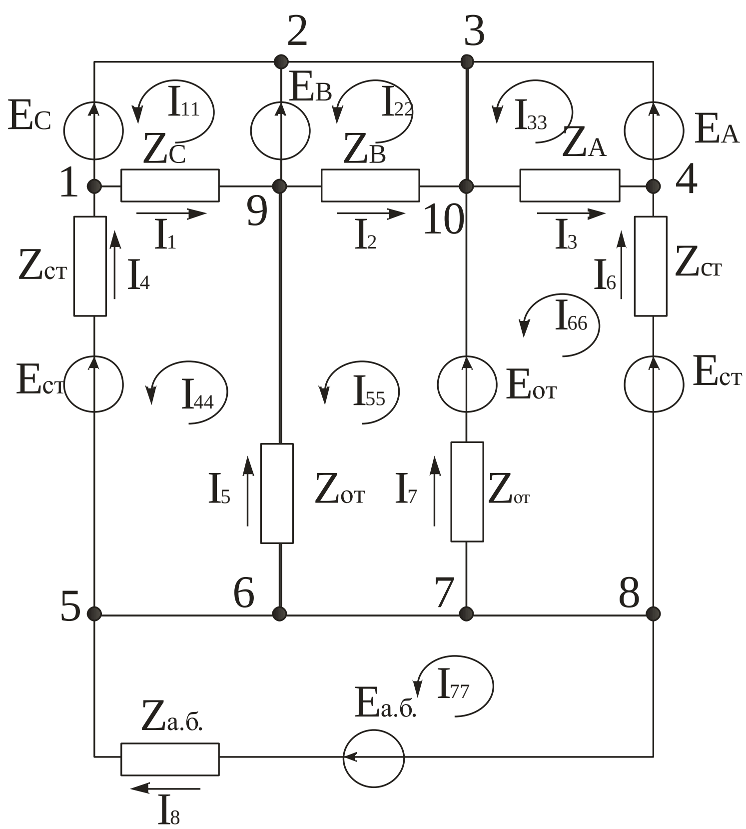

Fig. 3. The alignment of the currents of the equivalent circuit

To obtain the system of equations under the laws of Kirchhoff formulations of the first law equation for the nodes:

First node $I_4 - I_1 = 0$;

Second node $I_1 + I_2 = 0$;

Third node $I_2 + I_3 = 0$;

Fourth node $I_3 + I_6 = 0$;

Fifth node $I_8 + I_4 = 0$;

Sixth node $I_7 - I_5 = 0$;

Seventh node - no equation

Eighth node $-I_6 - I_7 = 0$;

Ninth node $I_1 + I_5 + I_2 = 0$;

Tenth node $I_2 - I_3 + I_6 = 0$.

On the second Kirchhoff's law form the equations for contours 11-77:

Contour 11: $-E_C = I_1 \cdot Z_C$;

Contour 22: $-E_B = I_2 \cdot Z_B$;

Contour 33: $E_A = I_3 \cdot Z_C$;

Contour 44: $-E_{CT} = -I_4 \cdot Z_{CT} - I_1 \cdot Z_C + I_5 \cdot Z_{OT}$;

Contour 55: $E_{OT} = -I_5 \cdot Z_{OT} - I_2 \cdot Z_B$;

Contour 66: $E_{CT} = I_6 \cdot Z_{CT} - I_3 \cdot Z_C$;

Contour 77: $-E_{a.b.} = -I_8 \cdot Z_{a.b.}$.

Thus, we obtain equations describing the equivalent circuit (1-7):

$$Z_{11}\cdot I_{11}+ Z_{12}\cdot I_{11}+Z_{13}\cdot I_{11}+Z_{14}\cdot I_{11}+Z_{15}\cdot I_{11}+Z_{16}\cdot I_{11}+Z_{17}\cdot I_{11}= E_C; \quad (1)$$
$$Z_{21}\cdot I_{22}+ Z_{22}\cdot I_{22}+Z_{23}\cdot I_{22}+Z_{24}\cdot I_{22}+Z_{25}\cdot I_{22}+Z_{26}\cdot I_{22}+Z_{27}\cdot I_{22}= E_B; \quad (2)$$
$$Z_{31}\cdot I_{33}+ Z_{32}\cdot I_{33}+Z_{33}\cdot I_{33}+Z_{34}\cdot I_{33}+Z_{35}\cdot I_{33}+Z_{36}\cdot I_{33}+Z_{37}\cdot I_{33}= E_A; \quad (3)$$
$$Z_{41}\cdot I_{44}+ Z_{42}\cdot I_{44}+Z_{43}\cdot I_{44}+Z_{44}\cdot I_{44}+Z_{45}\cdot I_{44}+Z_{46}\cdot I_{44}+Z_{47}\cdot I_{44}= E_{ст}; \quad (4)$$
$$Z_{51}\cdot I_{55}+ Z_{52}\cdot I_{55}+Z_{53}\cdot I_{55}+Z_{54}\cdot I_{55}+Z_{55}\cdot I_{55}+Z_{56}\cdot I_{55}+Z_{57}\cdot I_{55}= E_{от}; \quad (5)$$
$$Z_{61}\cdot I_{66}+ Z_{62}\cdot I_{66}+Z_{63}\cdot I_{66}+Z_{64}\cdot I_{66}+Z_{65}\cdot I_{66}+Z_{66}\cdot I_{66}+Z_{67}\cdot I_{66}= E_{ст}; \quad (6)$$
$$Z_{71}\cdot I_{77}+ Z_{72}\cdot I_{77}+Z_{73}\cdot I_{77}+Z_{74}\cdot I_{77}+Z_{75}\cdot I_{77}+Z_{76}\cdot I_{77}+Z_{77}\cdot I_{77}= E_{а.б.}. \quad (7)$$

Here Z_{11}-Z_{77} - proper loop resistance; Z_{12}, Z_{13}, Z_{14}... Z_{76} - the common contours of resistance.

EXPERIMENTAL STUDY OF THE MATHEMATICAL MODEL

The method given in Tamazov A.I. article was taken as a basis of calculation of sources of EMF for contours 11-33 (figure 3) [12].

Calculation was carried out according to the data obtained from help and technical characteristics of the high-voltage PB-500 support. According to calculation in a contour the EMF equal to $42{,}7\cdot 10^{13}$ V. Specific resistance of air is accepted 10 Ohms·m.

Thus on predesigns the current proceeding in these contours is in limits 40-50 мА.

Experiments which essence consists in measurements of the induced currents, proceeding on hawser quickdraw of a support were made.

Venue of pilot studies – a plot of the line No. 5138 of Nura-Agadyr, tension 500 kV.

As a result of experiment currents in the contour formed the top traversy support and quickdraw were determined by the ammeter of tick-borne type (contours 11-33, figures 3).

The discrepancy between the calculated values of the currents and obtained experimentally was 15-20%, which confirms the adequacy of the developed model with an accuracy sufficient for engineering calculations.

CONCLUSIONS

The universal model describing distribution of currents of leak on elements of a high-voltage support and currents of spreading in the soil is developed. According to help data model parameters are calculated.

On the existing 500 kV line conducted experiments to measure the currents induced procrastination. The difference between the calculated and measured currents did not exceed 15-20%, which confirms the possibility of using the model to analyze the processes occurring in the structural elements of high-voltage supports.

The model can be used to develop recommendations for a change to the support structure in order to minimize losses and calculating the parameters of the cathodic protection element bearing.

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