Galvanic effects of the gravitational network and measures to protect against it

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Abstract

The article examines the galvanic effects of the traction network on off-line adjacent lines and identifies insignificant electric shocks on adjacent lines due to the metal structures supporting the supports in the traction system, and significant measures on protection against galvanic effects. suggested.

Keywords: adjacent line, galvanic effect, cathode protection, tread protection, rail-ground resistance, drainage.

Introduction. Regardless of the voltage present in the AC traction network, a voltage is generated by the action of adjacent lines that is called the voltage caused by the action of the adjacent line or the induced voltage. Detailed information on the general conditions of induced voltage is given in several publications known to us.

In alternating and constant current networks, there is also a galvanic effect of the adjacent line relative to the cut-off line, its effect at alternating voltage is little studied due to its small size, and it is thought that the galvanic effect occurs mainly in constant lines. Several studies have also been conducted on the protection of other nearby lines from the galvanic effects of alternating current lines. As a continuation of this research, the article provides information on the process of studying the impact of adjacent lines on other nearby lines and structures, as well as the development of measures to protect against galvanic impact.

As a result of research, it became clear that the laws of galvanic action of the adjacent line with respect to the closed line are radically different from the laws of electrical and magnetic effects, and the most important of these effects are:

- grounded or underground lines (single-conductor chains, cables, underground metal devices and communications) are prone to galvanic effects of adjacent lines. It is known that for a galvanic effect to occur, the adjacent system must have at least two grounded points or galvanic contact with the rails and at least one grounded point;
- galvanic effect occurs as a result of currents leaking from the rails to the ground. Also, the potentials of individual points on the ground depend on the current value in the contact network, the resistance of the rails, the specific conductivity of the ground. Due to the heterogeneity of the earth's rocks and the change in currents in the rails, the law of change of the potentials of points on the earth in time and on the earth's surface is not constant near the rails;
- the maximum value of the voltage resulting from the galvanic effect is formed when the adjacent lines are perpendicular to the axis of the rail and (or) one of the poles in the single-conductor lines is far from the zero potential (Figure 1);
- for a 1000A contact network, the graphs given in the references are used to estimate the dependence of the U_g magnitude on the approximation width, the ground conductivity, and the depth of the armature. In these cases, the calculations are performed in two different modes (short circuit and forced) of the traction network. The galvanic effects of adjacent lines may not be taken into account if the specific earth conductivity in AC lines is more than 0.1 cm/m and (or) there are suction transformers in the traction network;

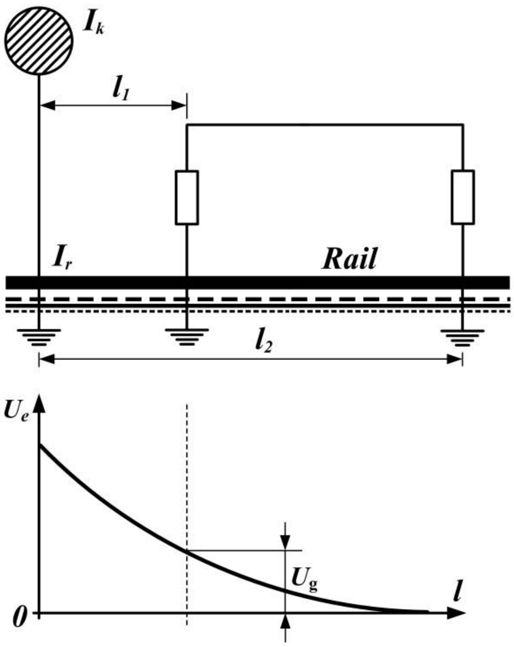

Figure 1. The voltage curve resulting from the galvanic effect

- the danger of galvanic exposure in areas electrified with alternating current is that it mainly causes electrical breakdown of underground devices.

Since the law of galvanic impact on the underground structures of adjacent lines is very complex due to the heterogeneity of the ground structure, we will consider only the general (main) part in order to simplify the process of analyzing the law of galvanic effect of lines adjacent to underground communications parallel to the railway line.

To assess the quality of the galvanic effects of the line adjacent to the underground structures, we use a scheme depicting an AC traction substation and a single electric locomotive (Figure 2a). In the picture, *R* – rails, *C* – communication (cable or tubular conductor), *l* – the distance between the loading and traction substation.

We analyze the processes in this system in terms of electrical breakdown. In addition to the main voltage drop in the traction substation occurring in the electric locomotive, there will also be a certain voltage drop in the contact network and rails (along with the ground). Due to the current flowing through the rails and the ground, the zero potential will be approximately located between the electric locomotive and the substation. In this case, the potential at the grounding point of the substation is negative, and the potential at the grounding point of the electric locomotive is positive. Figure 2b shows a graph of the coordinate distribution of the rail potential φ_r and the ground potential φ_{gr} under the rails.

Due to this potential difference, current flows from the rail to the ground, and we can see that the value of the current in the rail decreases from the substation to the center of the section and increases in the next interval due to the addition of current flowing through the ground to the rail (Figure 2c). Outside the traction substation section, the current flowing through the rails of the electric locomotive always flows in one direction and changes its direction in the opposite direction, as opposed to the current flowing through the ground,

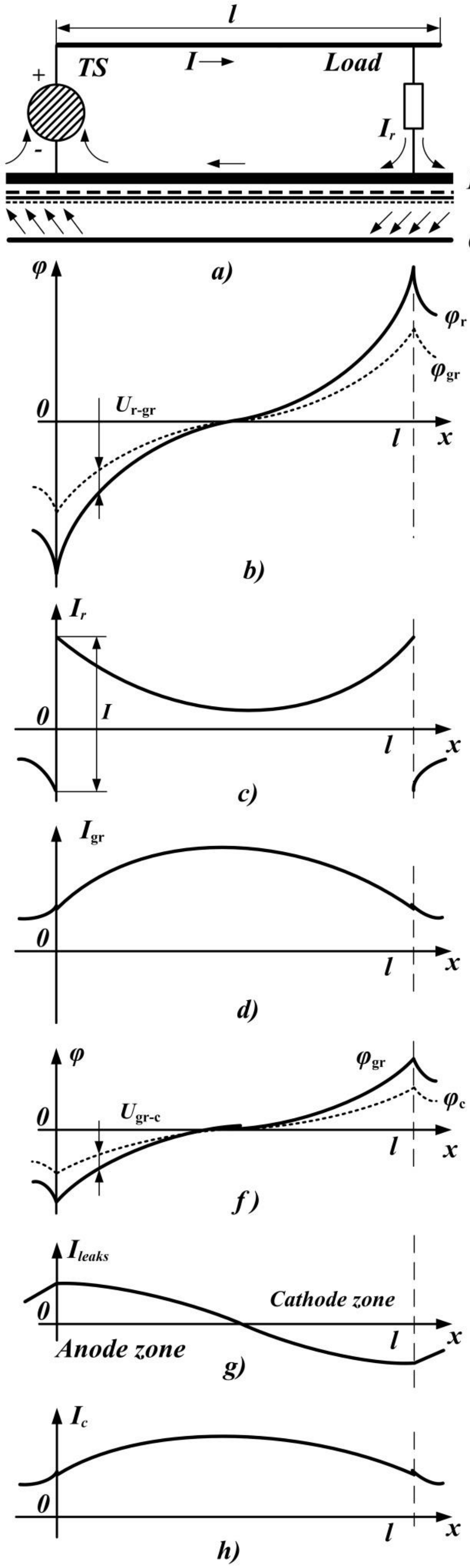

Figure 2 .

which increases with decreasing rail current (Figure 2d). The current flowing through the rails on both sides is equal to the contact current I and the current flowing through the ground is equal to the difference between the contact line and the rail currents ($I = I - I_r$). The distribution graph of the potentials of the underground structure and the ground next to it repeats the flattened view of the distribution graph of the rail potentials (Fig. 2f). In addition, as the depth of the ground increases, there is a decrease in potentials, and the difference between the potential of the structure and the ground causes a current flowing through the structure.

Figure 2g shows a graph of the distribution of current flowing through underground structures, where I_{leaks} - is the current flowing through 1 km of underground structures. Figure 2h shows the distribution of current flowing through the cross-sectional area of underground structures .

We analyze Figure 2g by dividing the underground structures into two parts. The first of these is the entrance part of the current to the underground structures, and the breakdown current in this section will be negative. It is called the cathode part because the potential around the underground structure is negative relative to the ground, and this part is near the electric locomotive. The second part is the outlet of the current from the underground structures, called the anode part, and it is located near the substation. The graph in Figure 2g shows that at a point where the rail potential on the module is relatively large, a relatively large current flows through the underground structure and the anode part of the underground structure is opposite to the cathode part.

The basis on which the communication is laid is electrically similar to the electrolyte, in which ions serve as electric charge carriers for current flow. In the electrolyte, the metal anode undergoes a constant electric decay, in which the metal release is directly proportional to the magnitude of the current flowing from the anode according to Faraday's first law of electrolysis. At large currents, distortions also occur in the cathode zones. These parts are constantly changing as the locomotives move. Therefore, based on the results of measurements carried out on the line, it is advisable to develop measures to protect underground structures from electric landslides.

As noted above, currents have a significant effect on underground structures of a certain length, but in AC electrified sections of alternating current, the effect of electrical breakdown on the contacts of the contact network must also be taken into account. Due to the fact that the metal structures of the supports are attached to the traction rail, they have the problem of electrical breakdown. If the metal structures of the supports are grounded according to other options, a large current will flow from the grounding when a hole occurs in the insulation of the contact network. This current value will not be sufficient to activate the protection elements during a short circuit, but they can cause the base structures to break very quickly or even collapse. The bases are usually grounded by means of a spark gap or protective diodes. Spark gap and protection diodes can usually fail due to overvoltages occurring in the rail (leakage current due to the voltage of the rail-ground and base resistance). When the supports are grounded in groups, a current flows between them (leakage current, which depends on the resistance of the supports and the rail-ground voltage). To determine the need to mount the spark gaps or install diodes when grounding the supports, the spark gaps and the foundation parts of the supports must first be inspected. To do this, appropriate measurements are made on the line. Since it is difficult to directly control the leakage current from the base, the value of the rail-ground potential at the location of the sieve and at the base resistance is measured.

The resistance of reinforced concrete supports consists of two components, namely the upper part resistance (supporting structures - reinforcement) and the reinforcement-ground resistance, usually the reinforcement-ground resistance is 60 Ohms (in most cases in the range of 10 ... 30 Ohms) and higher. The section resistance depends on the contact resistance between the clamp and the armature.

The potential difference between the rails and the ground is measured using a voltmeter with a high internal resistance, a zero point located between the scales, and a measuring range of 50-100 V. A steel pin or a non-polarized copper-sulfate electrode is used as the second electrode in the measurement process. The second electrode is placed in the ground in a line with the supports in the middle of the gap between the supports, and contact with the rails is made by installing a clamp on the bottom of the rails or connecting a conductor directly to the connection point of the rails. Measurements should be made at least every 1 km.

In the normal operation of the traction system, the voltage at each point is measured by taking certain values every 10 seconds for a period of not less than 5 minutes, as well as at least 1 train must pass during the measurement period. During the analysis of the measurement results, the negative and positive values of the potentials are separated and the average negative and positive values of the potentials for the measurement period and the total average values of the measurements are determined. By dividing the average positive potential value by the base resistance, the value of the current flowing through the grounding circuit from the base when the insulation is broken is determined. For reinforced concrete supports, the leakage current value should not exceed 40 mA.

The measurement results allow to control not only the potential difference between the rails and the ground, but also the leakage current of the traction current on the rails, the resistance of the rails at the connection point, the resistance of the rails, underground communication potentials and other parameters.

A number of measures have been developed to protect grounded or underground lines from the galvanic effects of adjacent lines, and we will theoretically cover the research conducted to increase the level of protection of these measures.

Measures to protect underground structures from galvanic effects are divided into two major groups, and the methods for this group are shown in Figure 3.

The method of reducing the value of current on the ground and rails reduces the current flowing from the rails to the ground when the distance between substations is reduced, but when the distance between substations is reduced, the formation of equalizing currents worsens the system.

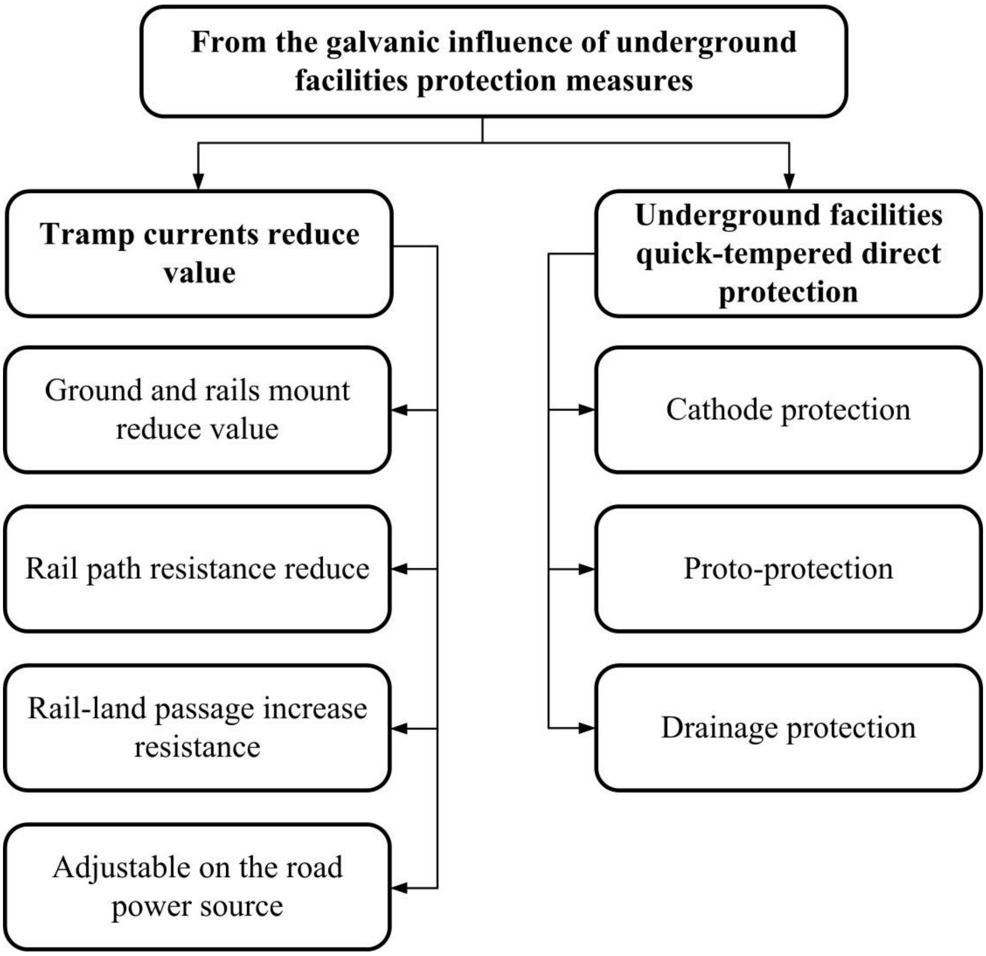

Figure 3. Measures to protect underground structures from galvanic effects

To reduce rail resistance, it is necessary to have a reliable and highly conductive contact at the rail connection points. Otherwise a reduction in rail path resistance cannot be achieved. In this case it is necessary to use long rails with no connection points or. This in turn leads to the economic cost of the system and complicates the construction process.

To implement the measure to increase the resistance between the rails and the ground, a drainage device is used for non-conducting dielectric impregnation on the sleepers, ballast shedding and dehumidification of the canvas.

It is advisable to use a voltage switching device that is connected to the separation points of the rails to carry out the adjustable current supply measure. (Figure 4a). The power supply of the switching device is provided by an alternating current network, the output voltage is controlled by the current in the contact network, and the rectifier current is adjusted approximately equal to the current in the contact network. The additional voltage generated by the adjustable current source

(Fig. 4b) forces the load current to flow along the rails (Fig. 4c). Also in this case the value of the load voltage increases by a very small amount and its power consumption is relatively small.

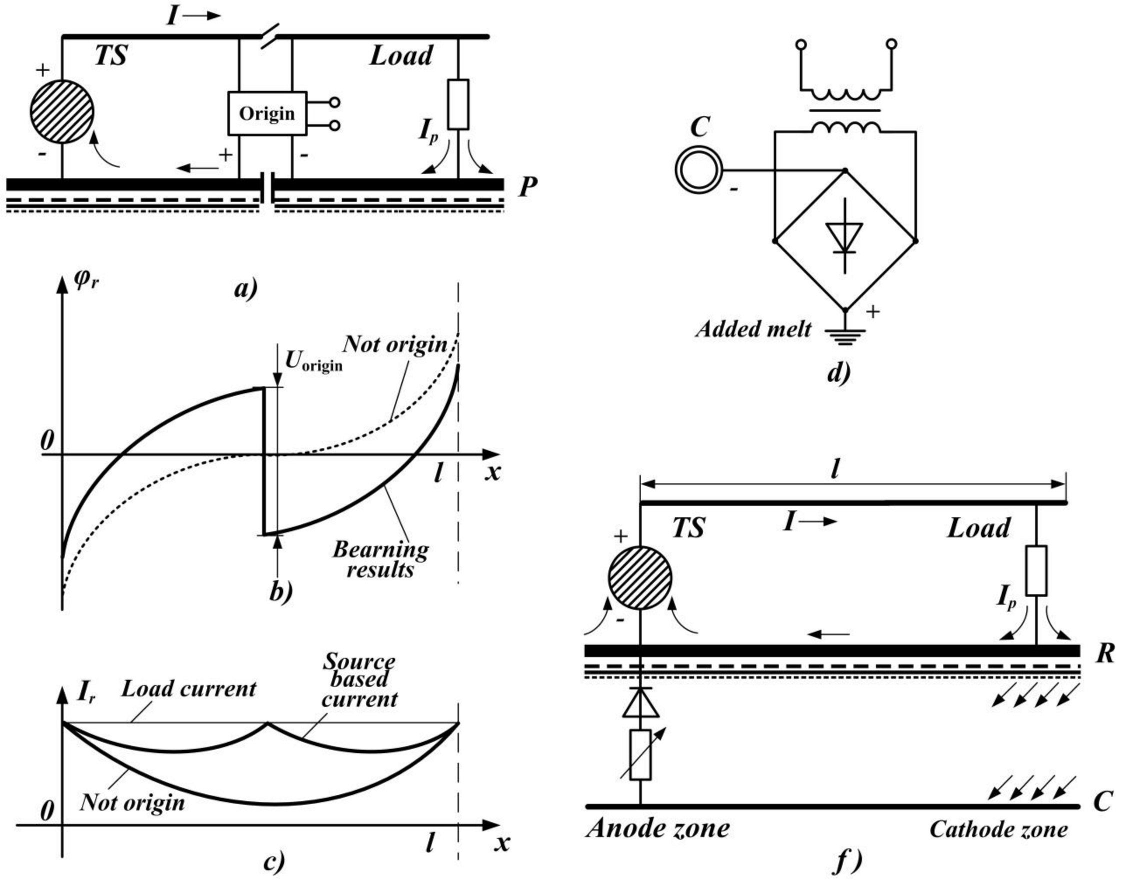

Figure 4.

The essence of cathodic protection, which is used in the direct protection of underground structures from galvanic influences, is that in the anode region of the underground structure is artificially formed cathode region from an additional voltage source (Fig. 4d). It is known that in this case the additional cathode of the cathode protection is intensively damaged. In the cathodic region of underground structures, the potential is further negative, which in turn leads to damage to the paint of the underground structure as a result of the release of hydrogen between the paint of the underground structure and the metal. For these reasons, the maximum value of the cathode protection potential is limited. The installation of cathodic protection must also take into account the possibility of potential changes in neighboring structures and the increase in their rate of decay.

Protective protection against erosion is the electrochemical protection of underground pipes using galvanic couple current. The principle of operation of tread protection is to protect the protected steel structure using the electrochemical potential of tread materials with high electronegativity potential (magnesium, aluminum and zinc-based alloys - anodes, some electrodes lost in the process). Due to the difference in potentials, the galvanic pair generates a current flowing from the anode (the anode of the electrode with the highest electronegativity) and from the electrolyte to the cathode. The purpose of generating current is to provide electrochemical protection against breakdown. When the tread anode breaks, its ions pass to the ground, and the released electrons flow into the cathode-tube with a negative charge, as if in excess. That is, under the influence of the EMF of the galvanic pair "pipe-tread" in the contour of the "tread-to-pipe" there is a protective current flow from the ground to the pipe, which should be formed in the electrochemical protection.

In drainage protection, the anode area of the underground structure is connected to the rails or the negative busbar of the substation (Figure 4f). In this case, the "drying" of electric charges in the anode region, ie drainage. The resistor R_∂ shown in the figure allows the ground potential to be adjusted, while the diode prevents the reverse current from flowing as a result of a sudden increase in the potential of the rails at the connection point. However, in the case of drainage protection, the leakage currents out of the rails increase and the process of erosion of the rails accelerates

With the help of the above measures, it is possible to further increase the level of protection by applying them together to protect underground structures from galvanic influences. However, using these methods, protection is more effective when only one of the electrical, magnetic, and galvanic effects of adjacent lines is present. When electrical, magnetic and galvanic effects occur simultaneously, it occurs in the form of the sum of magnetic and galvanic (almost no electrical effects) effects on grounded objects and the sum of magnetic and electrical effects for grounded lines. In this case, it is not sufficient to obtain the sum of the potentials from different sources according to the law of conservation of energy or the method of overlapping several currents. Therefore, for each case, it is necessary to first define the joiners and then add them.

In single-conductor cables with underground conductors and working conductors, and in overhead lines, the magnetic field voltage shifts by 900 to the applied current (current and voltage are sinusoidal), while the galvanic effect corresponds to the current phase of the contact network. In this case, since the adjacent lines have no electrical effect relative to the other lines, the sum of the voltages is determined using the following expression:

$$U_{\mathrm{M}g} = \sqrt{U_{\mathrm{M}g}^2 + U_g^2}$$

In the ground-insulated conductors of overhead lines, there will be electrical and magnetic effects of adjacent lines. In this case, when calculating the sum of voltages, it is necessary to take into account the difference between the phases of voltages U_M and U_e. According to the formula in Figure 5a and $\dot{E}_S = -j\omega \mathrm{M}\dot{I}_{\mathrm{K}} l s_r$, the magnetic stresses are determined using the following expressions at the beginning of the line $U_{\mathrm{M}0}$and at the end $U_{\mathrm{M}l}$:

$$\dot{U}_{MO} = \frac{1}{2} j\omega \mathrm{M}\dot{I}_{\mathrm{K}} l s_r; \qquad \dot{U}_{Ml} = -\frac{1}{2} j\omega \mathrm{M}\dot{I}_{\mathrm{K}} l s_r$$

The vector diagram is shown in Figure 5b, taking into account that the sum of these voltages with the applied voltage corresponds in phase with the contact line voltage, that the contact line current is approximately 37^0 angles behind the voltage, and that the vectors $U_{\mathrm{M}0}$ *and* $U_{\mathrm{M}l}$ are perpendicular to the current.

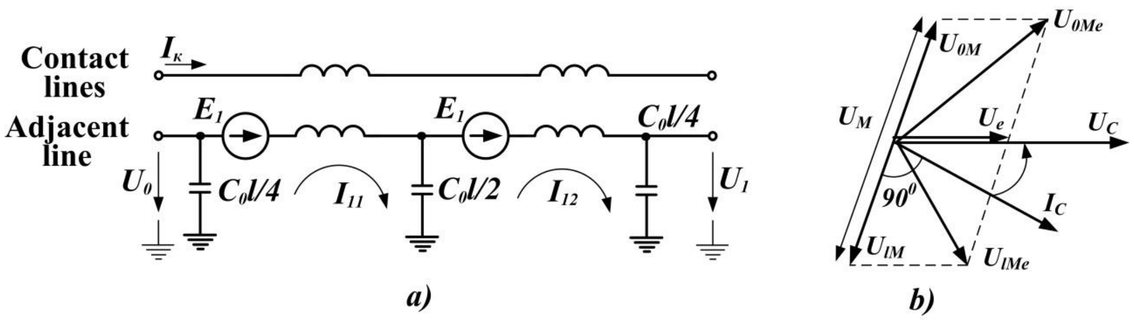

Figure-5

It is clear from the vector diagram shown in Figure 5b that the magnitudes U_{M0e} and U_{Mle} are not the same in terms of value and phase. In this case, according to the cosine theorem, the sum of the voltages is determined at the beginning and end of the line using the following expression:

$$U_{Me}=\sqrt{\left(\frac{U_M}{2}\right)^2+U_e^2\pm U_M U_e sin\varphi}$$

where $U_M - is$ the total voltage of the magnetic effect and it is equal to the EMF value.

$$U_{Me}=\sqrt{\left(\frac{U_M}{2}\right)^2+U_e^2}$$

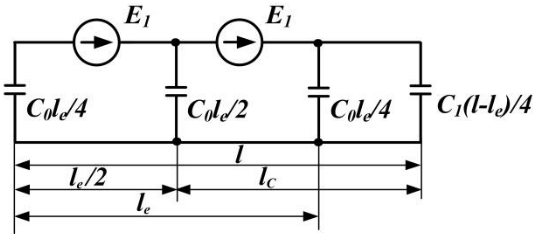

Figure-6

The last expression is reasonable for the situation when the adjacent line is in the full zone of influence. If the adjacent line cable extends beyond the boundary of the impact zone and its length l exceeds the section length l_e in the impact zone, the calculations become somewhat complicated. The corresponding scheme for this case is shown in Figure 2a. Figure 6 shows the switching scheme for calculating the voltages generated at the beginning of the line. This circuit consists of 3 contours, with no EMF source of magnetic effect in the last contour. The value of the capacitances between the ground and the conductor depends on the lengths of the corresponding sections. In the given switching scheme, it is not difficult to calculate the voltage across the left capacitor, and it is equal to the voltage $\frac{U_M l_C}{l}$. Where $U_M = 2E_1$, $l_c -$ is the distance from the center of the impact zone to the end of the adjacent wire. The voltage across the left capacitor U_M is determined using the effective length l_e. The last expression written to calculate the sum of the voltages at the beginning of the adjacent line is as follows after several:

$$U_{M0}=\sqrt{\left(\frac{U_M l_C}{l}\right)^2+U_e^2}.$$

Using this expression, it is possible to determine the sum of the voltages at the beginning of the line that are within the range of the adjacent line, and on the basis of the results obtained it is possible to draw a definite conclusion about the joint application of one or more of the above-mentioned protective measures.

Based on the study of the galvanic effect of the gravitational network and measures to protect against it, the following conclusions and conclusions were drawn:

the galvanic effects of the impact lines relative to the adjacent lines were found to be due to the presence of a metal connection of the object with the ground or rails, and in this case the number of damages or faults in the DC network was high;

it was found that the anode zones of underground structures, which are prone to erosion as a result of various influences of adjacent lines, are usually near the traction substations, so there is a lot of damage in these parts;

due to the fact that the metal structures supporting the supports in the traction system are connected to the rails, the electric breakdown under the influence of adjacent lines was insignificantly small in AC lines and significantly higher in AC lines;

based on the fact that for both cases it is possible to determine the square of the total effective voltage by the sum of the squares of the applied voltage when the adjacent lines are within two different effects (electric and magnetic or galvanic and magnetic) of the simultaneously acting lines.

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