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Ensuring the reliability of energy systems with the application of a new method of decreasing seasonal variations of ground resistance

Ivan Pavlovich[1]*, *Siarhei* Baraishuk [1], *Alexey* Skripko[2]

[1]BSATU, Department of practical training of students, 220023 Belarus, Minsk
[2] TerraCynk ltd. technical department, 220000 Minsk, Belarus

Abstract. The possibility of improving the reliability of the grounding system is shown. The analysis of dependence of soil resistivity on humidity was carried out, on the basis of which a composition for normalization (reduction of seasonality) of soil electrical resistivity was proposed. A number of full-scale experiments were carried out to measure the resistance values of the grounding devices of experimental circuits, after backfilling the places of laying the contour elements with various compositions and introducing other types of soils and minerals.

Introduction

For the uninterrupted operation of electrical installations, reliable grounding is necessary, which can reduce the risk of electric shock to maintenance personnel, as well as protect equipment. It is well known that the electrical resistance of the ground loop is determined by many factors, such as soil porosity, soil moisture, freezing depth, mineral salt content [2]. These parameters change throughout the year, so the so-called seasonal factor is introduced to calculate the ground loop.

The purpose of this work is to develop a method for reducing the influence of seasonality on the resistance of grounding devices.

1 Ways to reduce the seasonal factor

The current spreading resistance of a grounding device depends on the types of soil (sand, clay, limestone), particle size and density, humidity and temperature, as well as the chemical composition of the soil, the presence of acids, salts, alkalis in it [1, 2]. For seasonal influences on soil resistivity, in turn, the determining parameters are humidity and temperature [3 - 4]. It can be concluded that increasing the ability of the soil to retain water with minerals and salts dissolved in it in the near-electrode space improves the properties of the grounding device.

An analysis of the previously studied dependences of soil resistance on moisture, described in particular in [9], is in good agreement with the results obtained by the authors and presented in Figure 1 and shows that stabilization of soil moisture in the amount of 12-16 mass percent is optimal, a further increase in moisture is already does not lead to any significant decrease in resistance (Fig. 1).

One of the well-known ways to reduce the effect of annual temperature changes on the GD resistance is the use of deep ground electrodes. The disadvantages of this method include the high metal consumption of work.

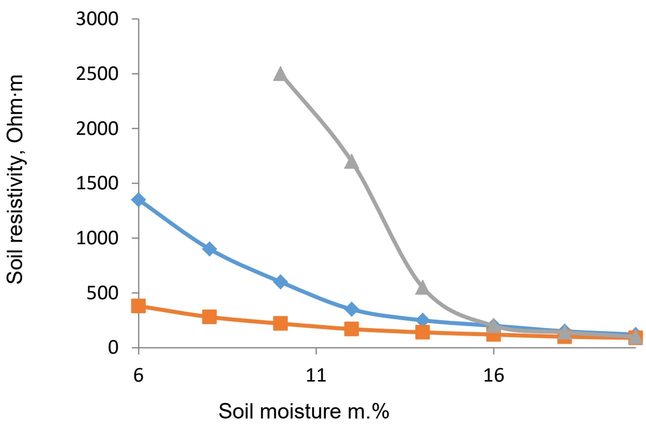

Fig. 1. Dependence of the specific resistance to current spreading of various soils on humidity, expressed in mass percent.

Another way to reduce seasonal fluctuations in resistance is to use electrolytic electrodes. Electrolytic grounding is a tubular electrode with a diameter of 50-110 mm and a length of 3 m, made of stainless steel with perforations on the walls. The electrodes are filled with an electrolyte based on mineral salts [6–7]. Known mineral activators produced in the CIS are a mixture of an ion-exchange salt modified with a halide

* Corresponding author: mrchesel20@gmail.com

activator and a surfactant. The disadvantage of such ground electrodes is the use of electrodes made of corrosion-resistant steel or non-ferrous metals as the electrode material [5]. Also, this method contributes to soil salinization and an increase in the rate of destruction of metal structures located in close proximity to the grounding device.

2 Experimental studies

In our research, a soil-substituting mixture based on hydrogel, bentonite clays, and graphite was developed. The use of hydrogels is due to its ability to bind water in the near-electrode space, helping to maintain stable humidity. Maintaining the same soil moisture throughout the year allows you to stabilize the amount of mineral salts dissolved in the soil, which has a positive effect on the resistance to the spread of electric current in the soil.

Fig. 2 shows the results of measurements of the specific resistance of a mixture of soil with hydrolyzed polyacrylonitrile in various proportions.

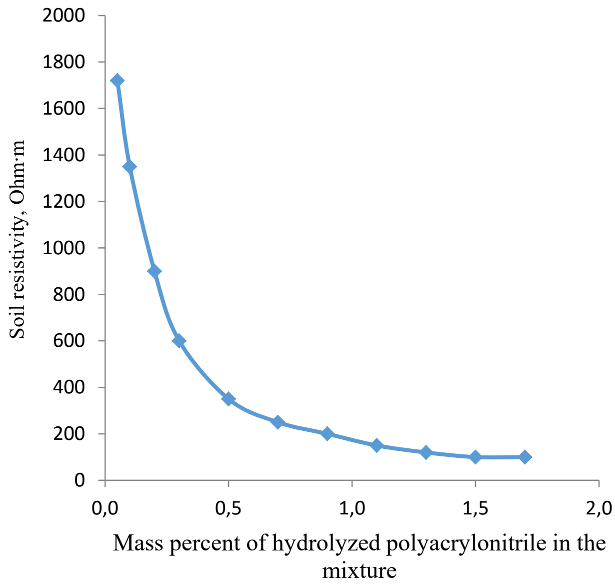

Fig. 2. Dependence of soil resistivity on the percentage of gel introduction based on hydrolyzed polyacrylonitrile.

As can be seen from the graph presented in Fig. 2, when hydrogels obtained by swelling hydrolyzed polyacrylonitrile with a dry weight of more than 1.3-1.5% of the soil mass are introduced, moisture stabilization occurs, and a further increase in concentration does not lead to a decrease in soil resistivity. , which indirectly indicates the optimal soil moisture.

The use of graphite in this mixture is necessary in order to compensate for the decrease in conductivity in mixtures when the water crystallization temperature is reached. The ongoing experimental and field studies have revealed that when using graphite powder, it makes it possible to keep the resistance of the mixture at a sufficiently low level, even at negative temperatures (Fig. 3).

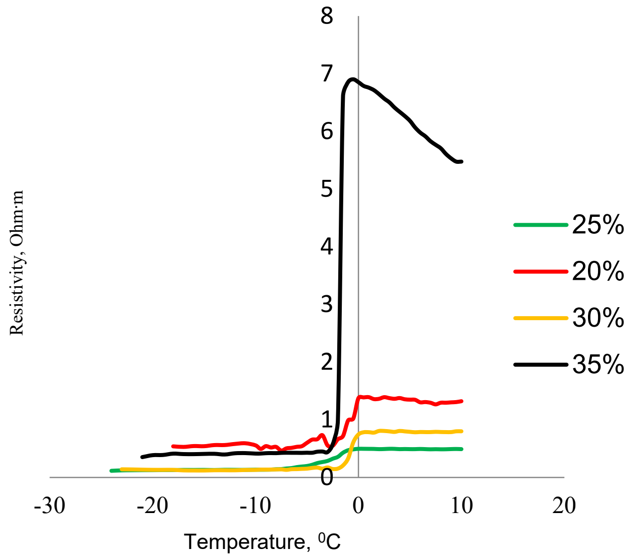

Fig. 3. Dependences of the specific resistance of the mixture on temperature at different humidity

For field experiments, grounding devices were mounted, which are two vertical electrodes made of ordinary black steel with a diameter of 12 mm and a length of 2 m. These vertical electrodes were connected by a horizontal strip 4x40 mm long 4 m. for the mixture. Systematic measurements of the control and experimental grounding devices were carried out using a four-wire method with an IS-10 meter, according to the method proposed by the manufacturer.

The results of experimental studies of the resistance of the control and experimental circuits are shown in Figure 4. From the data obtained, it can be concluded that the GD has the lowest resistance value, the near-electrode space of which is treated with an experimental mixture to reduce the spreading resistance of the GD. The results of the research show that the resistance of the ground loop changes slightly, which indicates that the influence of the seasonal factor has also decreased. It is worth noting the general decrease in the resistance of such a circuit, relative to the control one.

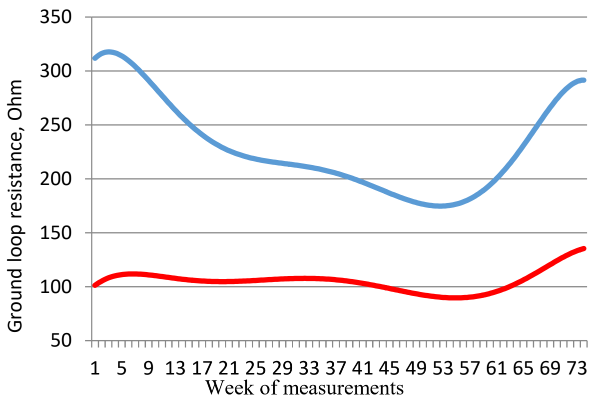

Fig. 4. Current spreading resistance values of the control (blue line) and experimental (red line) circuit, measured every week starting from September.

As can be seen from the graph, the use of hydrogel allows not only to reduce fluctuations in the resistance to spreading of the GD, but also to reduce the resistance of the GD in comparison with the control circuit. The use of the proposed additive also reduces the freezing temperature of the soil by 4-6 ºC, which makes it possible to use higher average long-term low temperatures when determining the climatic zone of the site for the location of the designed electrical equipment, and to reduce the seasonality coefficients when interpreting field measurements. The conducted studies have shown that the effect on the decrease in electrical resistance can be divided into 2 factors: a change in the seasonality factor and a decrease in the specific resistance of the soil in the near-electrode space, which makes it possible to make adjustments to the calculations of the resistance of the ground electrode when using mixtures during the installation of the GD. It is obvious that the efficiency of such a replacement is the higher, the greater the difference in the electrical resistivity of the soil and the mixture, as well as the greater the amount of soil replaced in the near-electrode space. However, previous studies [6] showed that there is a relatively small optimal volume (~10 cm in the radius around the electrodes) when such a replacement is most effective and a further increase in the volume of the soil to be replaced loses its efficiency according to an exponential law.

This will ensure the longest possible prevention of soil freezing in the autumn-winter period, which is one of the factors for the high-quality operation of the grounding device.

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Conclusion

The use of a soil-substituting mixture makes it possible to reduce the effect of seasonal temperature fluctuations, which allows the ground loop to perform its functions stably, which favorably affects the stability and reliability of energy systems. Reducing the influence of external factors on the resistance of the grounding device will allow a more rational approach to the consumption of materials and reduce labor costs, as well as increase the reliability of grounding and electrical installations in general. The method developed by us to reduce the seasonality factor by using a soil-substituting mixture in the near-electrode space makes it possible to use ordinary black steel [5].

References

1. Vedeneeva L.M., Chudinov A.V. Study of the influence of the basic properties of the soil on the resistance of grounding devices // Bulletin of the Perm National Research Polytechnic University. Geology. Oil and gas and mining. - 2017. - V. 16, No. 1. - S. 89-100.
2. Trifunovic J., Kostic M. Analysis of the effect of imperfect contact between ground electrodes and the surrounding soil on the electrical properties of ground loops // Electrical engineering. - 2014. - T. 96. - No. 3. - S. 255-265.
3. IEEE Std 142-2007 IEEE Recommended Practice for Grounding Industrial and Commercial Power Systems. - Approved. June 7, 2007 - 225 p.
4. J. He, R. Zeng, Y. Gao, Y. Tu, W. Sun, J. Zou, et al. Seasonal Impact on the Safety of a Substation Earthing System IEEE Trans Power Delivery, 18(3) (July 2003)
5. Drako M.A. Corrosion of ground electrodes of electrical installations // Energy strategy, 2019, no. 6 (69), p. 44–48.
6. S.M. Baraishuk, I.A. Paulovich, M.Kh. Murodov, Kh. Abdulkhaev, A.N. Skripko Reducing the resistance of grounding devices by using soil treatment with moisture-stabilizing additives that are non-aggressive to the grounding material // Agropanorama.– 2021. – No. 5 (147).– P. 28–33/
7. Noskova S.V. Resistance of an electrolytic ground electrode. Calculation features // News of Electrotechnics. - 2020 No. 1 (121) - 2 (122). - With. 72-77.
8. Gribanov A.N. Bipron - grounding of electrical installations // Exposition Oil Gas, .– 2016 .– No. 4 .– p. 72-75.
9. P.A. Ferre, J.D. Redman, D.L. Rudolph, and R.G. Kachanoski, "The dependence of the electrical conductivity measured by time domain reflectometry on the water content of a sand", Water Resour. Res., 1998.