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Ensuring the Reliability of Energy Systems with a New Method for Reducing Seasonal Variations in Ground Resistance

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Abstract — **The paper shows the possibility of improving the reliability of a grounding system. The moisture dependence of soil resistivity is analyzed. Based on the analysis, the soil composition was proposed to normalize (reduce seasonality) its electrical resistivity. Several full-scale experiments are carried out to measure the resistance of grounding devices of experimental circuits, after backfilling the places of laying the circuit components with soil of various compositions and using other types of soils and minerals.**

Index Terms: **Resistance, grounding circuit, hydrogel, graphite, deep-driven electrode, near-electrode space, seasonality coefficient.**

I. Introduction

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

This study aims to develop a method to reduce the effect of seasonality on the resistance of grounding devices.

II. Ways to Reduce the Seasonal Coefficient

The spreading resistance of a grounding device depends on the types of soil (sand, clay, limestone), particle size and density, moisture and temperature, as well as the chemical composition of soil, i.e., the presence of acids, salts, and alkalis in it [1, 2]. The determining parameters for seasonal effects on soil resistivity, in turn, are moisture and temperature [3, 4]. It can be concluded that an increase in 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 moisture dependences of soil resistance, which are described, in particular, in [9], indicates their good agreement with the results obtained by the authors and presented in Fig. 1. The analysis shows that stabilization of soil moisture occurs at 12–16 mass percent and it is optimal, since further increase in moisture no longer leads to any significant decrease in resistance (Fig. 1).

One of the well-known ways to reduce the effect of change in annual temperature on the grounding device resistance is the use of deep-driven electrodes. The disadvantages of this method include the high metal intensity of work.

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, 3 m long, which is 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 activator and a surfactant. The disadvantage of such grounding electrodes is the use of corrosion-resistant steel or non-ferrous metals as an electrode material [5]. In addition, 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.

III. Experimental Studies

The research presented in this paper involved developing a soil-substituting mixture based on hydrogel, bentonite clays, and graphite.

The use of hydrogel is due to its ability to bind water in the near-electrode space, which helps to maintain a stable moisture level. Maintaining the same soil moisture throughout the year allows stabilizing the quantity of mineral salts dissolved in the soil, which has a positive

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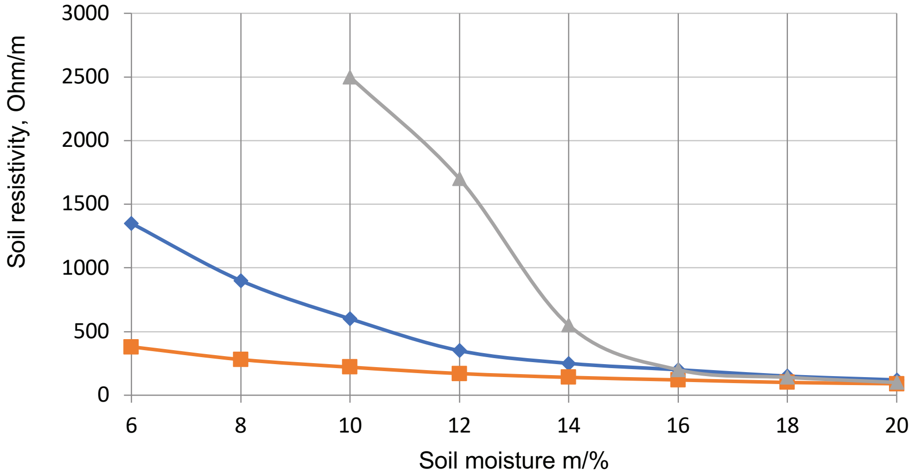

Fig. 1. Relationship between spreading resistance of various soils and moisture, expressed in mass percent.

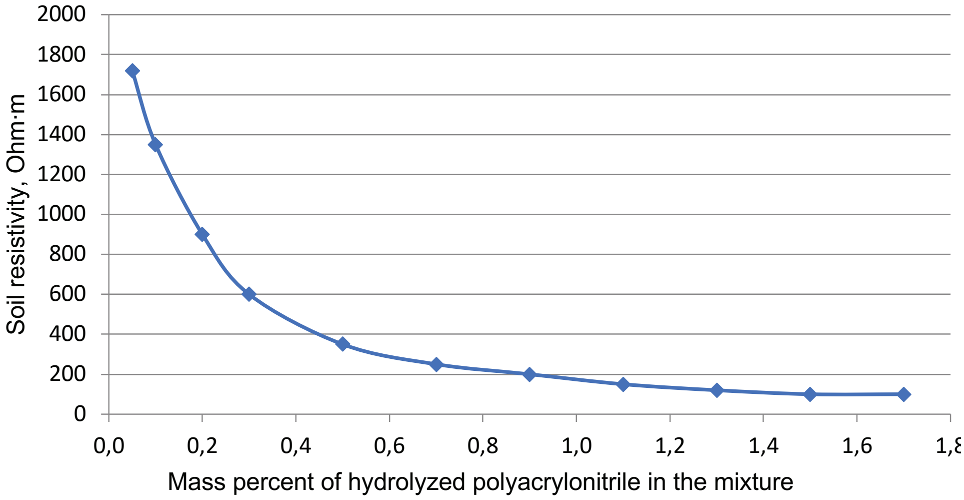

Fig. 2. Relationship between soil resistivity and percentage of injected gel based on hydrolyzed polyacrylonitrile.

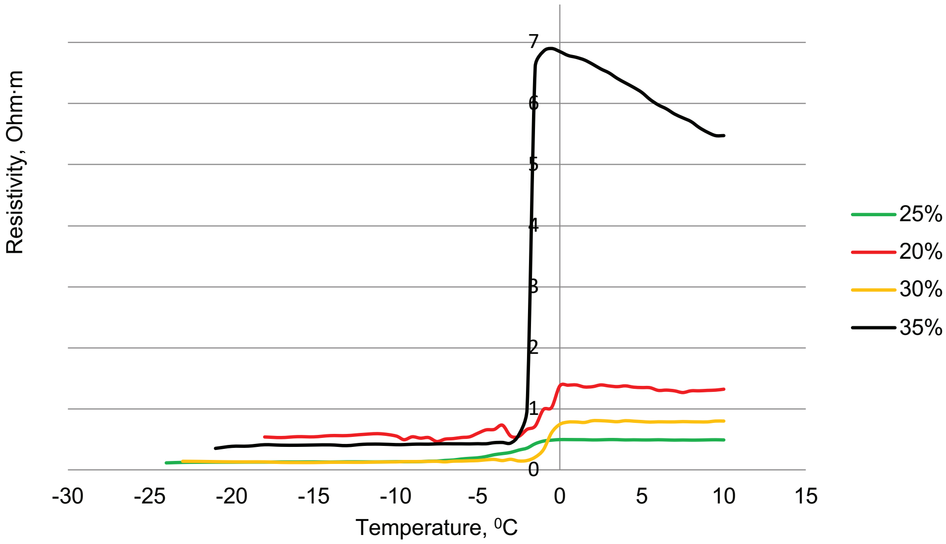

Fig. 3. Temperature versus resistivity for the mixture at varying moisture.

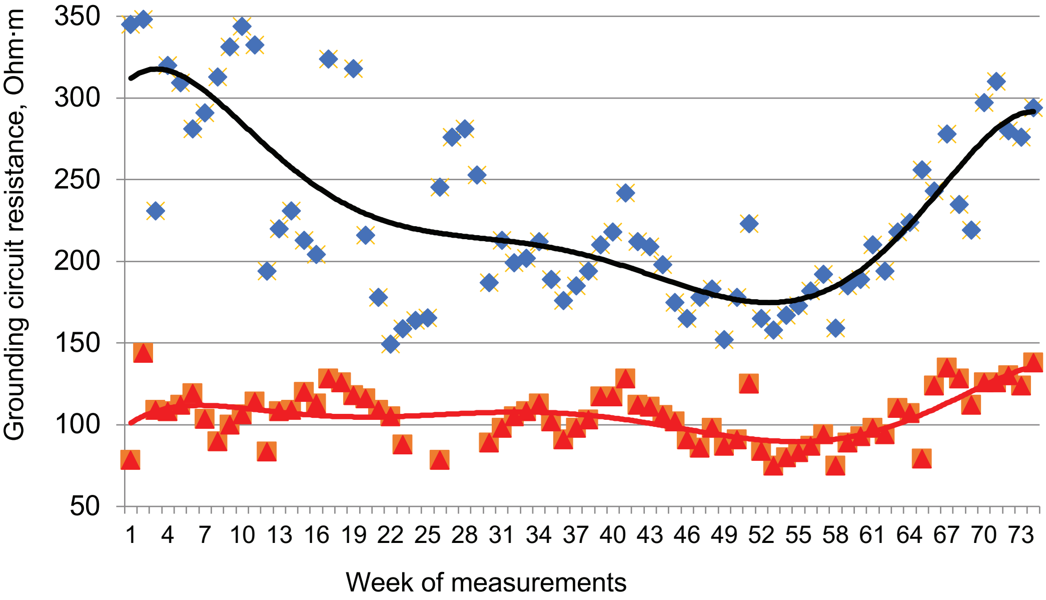

Fig.4. Values of spreading resistance for the control circuit (blue markers and line) and experimental circuit (red markers and line), measured every 10 days, starting in September.

effect on the spreading resistance in the soil.

Figure 2 shows the results of the resistivity measurements for a mixture of soil with hydrolyzed polyacrylonitrile in various proportions.

As seen in the graph presented in Fig. 2, with hydrogels obtained by swelling hydrolyzed polyacrylonitrile with a dry weight of more than 1.3–1.5% of the soil mass, moisture gets stabilized, and a further increase in concentration does not lead to a decrease in soil resistivity, which indirectly indicates that the optimal soil moisture is obtained.

The use of graphite in this mixture is necessary to compensate for the decline in conductivity in mixtures when the crystallization temperature of water is reached. Conducted experimental and field studies revealed that the use of graphite powder allows keeping the resistance of the mixture at a low level even at sub-zero temperatures (Fig. 3).

Field experiments involved the installation of grounding devices consisting of 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 4 × 40 mm horizontal strip, 4 m long. During the installation, the soil in the near-electrode volume of soil of the experimental circuit was replaced with a mixture. Systematic measurements of the control and experimental grounding devices were carried out using a four-wire method with an IS-10 measurement device, according to the method proposed by the manufacturer.

The results of experimental studies on the resistance of the control and experimental circuits are shown in Fig. 4. The data obtained enable us to conclude that the lowest resistance value is characteristic of the grounding device whose near-electrode space is treated with an experimental mixture to reduce the spreading resistance of the grounding device. The findings suggest that the resistance of the grounding circuit changes slightly, which is also an evidence of the decrease in the influence of the seasonal coefficient. It is worth noting that there is an overall decline in the resistance of such a circuit with regard to the control one.

As seen in the graph, the use of hydrogel reduces not only fluctuations in the spreading resistance of the grounding device but also the resistance of the grounding device in comparison with the control circuit. The use of the proposed additive also decreases the freezing point of the soil by 4–6°C, which makes it possible to use higher average long-term low temperatures when determining the climatic zone of the site for the electrical equipment to be designed, and to reduce the seasonality coefficients when interpreting field measurements. The conducted studies show that the effect on the reduction in the electrical resistance can be divided into 2 factors: a change in the seasonality coefficient and a decline in the soil resistivity in the near-electrode space, which allows adjusting the calculations of the ground electrode resistance when using mixtures during the installation of the grounding device. It is obvious that the larger the difference in resistivity between the soil and the mixture, and the greater the amount of soil replaced in the near-electrode space, the higher the efficiency of such a replacement. However, the previous studies [6] indicate that there is a relatively small optimal volume (~10 cm in a radius around the electrodes) when such a replacement is as efficient as possible and a further increase in the volume of 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.

IV. Conclusion

The use of a soil-substituting mixture reduces the influence of seasonal temperature fluctuations, thereby providing stable performance of the grounding circuit functions, which has a positive effect on the stability and reliability of energy systems. Reduction in the influence of external factors on the resistance of the grounding device will enable a more rational approach to the consumption of materials and a reduction in labor costs, and will improve the reliability of grounding and electrical plants in general. The method developed to reduce the seasonality coefficient by using a soil-substituting mixture in the near-electrode space allows the use of ordinary black steel [5].

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