Effects of acidic water containing tailings on the insulation of electrical cables

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ABSTRACT : In this work are analyzed the causes of failure of the electrical power cables laid in areas with high pollution level. The research was mainly aimed at identifying the effects of acidic water with sterile content on the insulation of electrical cables with low natural aging degree (recently pictured) and analyzing the results of the pH measurements of the water samples in the vicinity of the cable routes, harvested during the performance of the defectoscopy operations, in three different areas. The case presentation describes in detail the stages of prelocation and location of the fault at a medium voltage cable posed in the "Saint Helena" Wind Park in Coronin, jud. Caras-Severin, an area where the measured pH values recorded the highest acidity content in the soil water. The cable broke down as a result of the penetration of the polymeric insulation next to the shrinkable sleeve, caused by contact with acidic water containing sterile.

KEY WORDS: environment polluted with tailings, acidic pH, penetration of insulation

1. INTRODUCTION

The safety in operation of electricity cables is influenced by a number of factors of a mechanical, electrical and environmental nature. A particular problem is the demands of the environment in operation, especially in areas with intense pollution. In regions with mining activity, pollution research [1] has shown a higher degree of pollution, primarily as a result of poor management of waste resulting from exploitation. One polluting element is tailings, with a major impact on the environment, as acidic waters and toxic substances (as the main results of tailings) directly affect the insulation systems of electricity cables. Tailings is an acid solid substance that in combination with water forms a solutionlichidă foarte corozivă. În momentul în care substanța electrolitică ajunge în zona de pozare a cablurilor de energie electrică și intră în contact cu suprafața lor exterioară, determină faster deterioration over time of the properties of the insulating materials that are part of the insulating system. Defects arise as a result of the penetration of electrical insulation due to the ingress of corrosive substances through the polymeric protective layer of the electrical cable. Although the laying of electrical cables in areas with pollution above the standard level is carried out according to the norms in force [2] in protective tubes, in operation there are situations in which this operation was carried out directly, without additional protections and without an analysis of the impact of the respective environment on the electrical insulation. During the processes of detection and repair of defects, portions of soil were identified on the electrical cable routes in which the tailings layer solidified including in its structure and the cable circuits existing in the area [3-6]. This fact causes the polymer insulation to plasticize over time, causing cracks. At the moment when the soil moisture rises (especially in rainy seasons), water penetrates through cracks inside the insulation, giving rise to the phenomenon of penetration.

At the same time, from the point of view of acidity, the sterile substance dissolved in water causes a rapid degradation of the insulating material, which undergoes internal chemical changes, losing its insulating properties. In most cases, the identification of defects is carried out by means of a defectoscopy autolaborator equipped with special pre-location and localization equipment. Operators have at their disposal a number of identification methods that they select according to the situation encountered on the ground. Since in most cases it is necessary to repair the defects in the shortest possible time, the chosen method of defectoscopy must be the fastest and most effective [7-11]. In practice, the most often used are: the pulse method known as the reflected arc method (ARM), correlated with the acoustic method, and the induction method. The pulse method is a method of prelocation of defects, with measurement errors, but very effective due to the fact that it substantially reduces the search area. The principle is based on the transmission of a voltage pulse in the cable to one of its ends, with a certain speed and its reflection from the fault site at the same speed, but of the opposite direction [12,13].

By calculating the time interval from the moment of departure of the impulse until the moment of its return to the starting point, the relative distance to the place of defect is calculated [13]. For the exact location, the acoustic method consisting in intercepting the noise produced by the electrical discharge at the fault site with a portable receiver with sound amplification, equipped with a high-sensitivity microphone, shall be used. Basically, the receiver operates on the principle of triggering two signals (acoustic and electromagnetic), and the moment of their overlapping coincides with the moment of localization of the defect [12]. This method is in some cases ineffective, especially in crowded areas or in special climatic conditions (wind, precipitation, etc.), situations that generate noise pollution. In such cases, interception is more difficult . The induction method is a method of localizare which has as its principle the interception of the electromagnetic field around the cable created by an injection current from an audiofrequency generator.

The audiofrequency signal intercepted by means of a search coil (mobile receiver) becomes maximum or minimum on the defective portion, accurately indicating the location of the defect [13].

2. MEASUREMENT OF PH ACID WATER IN THE SURROUNDINGS OF CABLE TRAILS

Detecting defects in electricity cables involves a series of steps and operations to repair and re-release as quickly as possible. After the stages of prelocation and exact location of the defect on the cable route, the next operation consists in carrying out the excavation for the removal of the earth layer from the area of the site of the defect, an occasion that gives the possibility of researching the environmental conditions in the soil. In most cases, excavations carried out during the wet periods of the year, (September-March) revealed a high degree of soil moisture in the vicinity of the cable path, with portions of cable actually submerged in the water coming from the infiltrations . Figure 1 shows several cases in which water infiltrations penetrated into the laying areas of electrical cables, causing penetrations of electrical insulation.

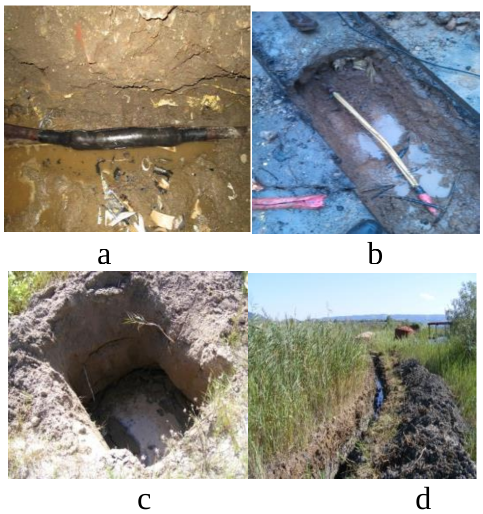

Figure 1. Areas with high humidity in the vicinity of cable routes:a)Zona Lugoj(driveway pedestrian on the shore Timișului); b) Zona Reșița (Ateneu); c) Area

Platoul Coronin (Parc Eolian " Sfânta Elena");
d) Area Moldova Nouă (Estacadă - Insula Ostrov)

With the help of a digital pH meter with temperature compensation, the pH values of the collected water samples were measured and recorded. Thus, measurements were made in three distinct areas: the area Reșița and area Moldova Nouă, din județul Caraș-Severin respectively the area Lugoj, din județul Timiș. The pH measurement is carried out on a logarithmic scale, from 0 to 14. A water-based solution has maximum acidity for a pH= 0 and becomes neutral for a pH=7 [14-16]. For pH values in the range of 5,5 to 6, the acidity is considered moderate and for a pH in the range of 5,5 to 0, the acidity is considered high [14]. The results obtained indicated a high acidity of the water in the industrial area of Resita as well as in the Coronini - Moldova Nouă area, where sterile substances in the solid state were also identified, but also traces of diluted tailings, in the composition of the water. In the area Lugoj, the measurements indicated a higher pH, respectively, a moderate acidity, although it is a fairly industrialized area.
With the help of a digital pH meter with temperature compensation, the pH values of the collected water samples were measured and recorded. Thus, measurements were made in three distinct areas: the area Reșița and the area Moldova Nouă, from the county Caraș-Severin respectively the area Lugoj, din județul Timiș.
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Table 1. Water pH in the vicinity of the cable routes: Lugoj area, Resita, Modova Nouă

Area	pH measured	Observations on the soil
Lugoj(aleea pietonală de pe malul râului Timiș), jud.Timiș	5,4	Very moist soil and low content of industrial by-products.
Reșița (Ateneu), jud.Caraș-Severin	4,6	Soil with medium humidity and content of industrial secondary products (blast furnace slag, metal and non-metallic powders)
Platoul Coronini (Parc Eolian "Sfânta Elena"), jud. Caraș-Severin	4,2	Soil with medium humidity and content of sterile industrial sand mine coming from the technical tailings pond Tăușani (currently dried up).
Moldova Nouă (Estacadă - Insula Ostrov), jud. Caraș-Severin	3,8	Very moist soil containing metal powders and sterile industrial sand mixed with water.

Thus, measurements were made in three distinct areas: the area Reșița and area Moldova Nouă, in Caraş-Severin County and lugoj area, in Timiş county. The pH measurement is carried out on a logarithmic scale, from 0 to 14. A water-based solution has maximum acidity for a pH= 0 and becomes neutral for a pH=7 [14-16]. For pH values in the range of 5,5 to 6, the acidity is considered moderate and for a pH in the range of 5,5 to 0, the acidity is considered high [14]. The results obtained indicated a high acidity of the water in the industrial area of Resita as well as in the Coronini - Moldova Nouă area, where sterile substances in the solid state were also identified, but also traces of diluted tailings, in the composition of the water.

In the Lugoj area, the measurements showed a higher pH, respectively a moderate acidity, although it is a fairly industrialized area. The measured values are shown in Table 1.

2. RESULTS AND DISCUSSION

In order to highlight the effects of acid water pollution on the insulation systems of the electricity cables in operation, an operation to identify and repair the defect in a medium voltage electricity cable with a short service life (6-7 years) is presented below, laid in an environment polluted with tailings, coming from a former copper extraction mine in the Moldova Noua area, Caras-Severin County. The cable typeARG7H1(3x1x500 mm2), having an approximate length of 7000 meters, operates at a nominal voltage of 18/33kV and provides the connection between the 30/110kV connection substation and part of the wind turbines of the " Saint Helena " wind farm. Insulation resistance measurements on all three individual phases showed a small value (88kΩ) between the circuit corresponding to the R-phase and the earth's potential. The values measured on the other two cable circuits were normal, falling within the GΩ range. The prelocation and localization of the defect of the R phase circuit was performed with the help of an auto-laboratory defectoscopy using the arm reflected arc method. Immediately after the resulting reflectogram on the teleflex screen indicated a distance of 3200 meters to the place of the defect, it was started on the cable route, with the help of a vehicle and monitoring the distance traveled on the mileage indicator. For the exact location of the defect, the mobile defect lessor was used, which was moved on the cable route in the prelocalization area. A low-intensity signal was intercepted, the operation being also hampered by environmental conditions, due to the wind blowing with power and introducing a background noise into the headphones of the audio receiver. At the same time, during the identification and repair of the defect, the atmospheric precipitation also appeared, the noise produced by the raindrops upon contact with the ground being intercepted in the headphones of the acoustic location receiver.

The existing environmental conditions determined the abandonment of the ARM method, still using the induction method. For this purpose, an audiofrequency signal of 8.44 kH was injected into the faulty cable circuit and the operation of locating the defect was restarted by moving the mobile audiofrequency receiver along the route portion. When intercepting a signal of maximum intensity, the search was interrupted and the excavation was ordered to be carried out near the localized portion.

The excavation was carried out gradually and very carefully in order not to compromise the other existing cable circuits by accidentally hanging with the excavator's bucket.

In the first phase, the earth was mechanized to the warning film arranged over the cable when laying, and it was noted the existence of a white dust (sterile sand) in the composition of the soil above the cable route (fig. 2).

Figure 2 . Identification at the site of the defect of a layer of sterile sand (white) that was also observed along the cable path in the stripped portion

In the second phase, in order to avoid hitting or breaking the cable circuits with the excavator's bucket, the earth was removed manually until the defect was viewed with the naked eye. It was observed that the sterile substance resulting from the mixture with the water on the defect portion solidified, probably as a result of temperature differences, comprising in its structure all three cable circuits. This state exerted a pressure (mechanical stress) on the insulation and limited the temperature exchange of the cable circuits with the medium (Fig. 3).

Figura 3. Identificarea defectul de manșon pe porțiunea cu steril solidificat

The defect was identified in a shrinkable sleeve whose insulation was effectively destroyed, becoming a gelatinous mass as a result of the acidic effect of water with sterile content (fig. 4).

Figure 4. The place of penetration of the shrinkable sleeve as a result of the degradation of the external insulation

The cable was repaired by replacing the sleeve, the sleeve operations being carried out in conditions of very high humidity and in the reflector light. The area where the sleeve was carried out was protected against the ingress of rainwater by installing a tent for rapid intervention and the solidified tailings portion was removed and replaced with a layer of protective sand (fig.5).

Figure 5. The final stages of repairing the defect: a) The operation of mounting the sleeve in conditions of high humidity ; b) Removal of the tailings from the cable route and laying in the sand of the portion of the cable sleeved

CONCLUSION

- In operation, electricity cables are subjected to a series of stresses that ultimately cause the degradation of the electrical insulation and their failure; - During the processes of identification and repair of defects in the cable, it was concluded that the action of environmental factors on the insulation of electricity cables is aggressive, uncontrolled and unpredictable; - Water pH measurements in the vicinity of cable routes indicated high acidity near industrial, mining and former mining areas.;- In the Moldova Noua area, they were identified tailings deposits (sterile industrial sand) in the vicinity of cable routes. At the same time, the whitish appearance of the water sample collected from this area confirmed the existence of the tailings in diluted form in the acid concentration of the water;

- The case presentation highlights the aggressive action of the acidic substance with sterile content on the polymeric insulation of the shrinkable sleeve that effectively caused the transformation of the insulating layer into a gelatinous mass, causing the defect to appear. - The establishment of the routes of the electricity cables in the design phase must take into account the impact of the environmental factors specific to the laying area (water, wind, chemicals, etc.) on the insulating system and ensure the minimum conditions of insulation protection, according to the norms in force.

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