Investigations of Earthing Components Corrosion in Different Climatic Conditions

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***Abstract*— The paper is addressed to studies of earthing system components corrosion in different climatic conditions based on comparative field tests results from Poland, North Africa and China. The paper is continuation of the paper presented at ICLP 2010 in Cagliari, and contains discussion and analyses of new field corrosion tests and observations performed in Sudan, which is located in warm, dry (arid), desert climate.**

Keywords - earthing electrode, corrosion, climatic conditions

I. Introduction

Components of earthing system for different applications, including power installations and lightning protection, which are buried in soil (earth electrodes and conductors) are subject to much harsher conditions than the components installed above ground. The service lifetime of earthing system is determined primarily by their ability to resist the corrosion.

Corrosion of earth electrodes is caused by electrochemical processes in soil or by stray currents in the earth and occurs at a rate depending on the type of soil and material of electrodes and the nature of the environment. Environmental factors such as moisture, dissolved salts forming an electrolyte, degree of aeration, but also seasonal temperature variations and extent of movement of electrolyte combine to make this condition a very complex one.

A special attention shall be also taken to influence of atmospheric and climatic conditions, which are varying in very big ranges worldwide. The characterization of global climatic conditions is illustrated in Fig.1, where the map of world climate classification is shown [1].

At the ICLP 2008 in Uppsala and 2010 in Cagliari [2,3] have been presented corrosion field test results in natural conditions of earth electrodes embedded in different soil types and climatic conditions – in Poland, Saudi Arabia, Libya and China (locations are marked in Fig.1). In the presented paper are discussed new field test extended results of corrosion of earth electrodes installed in arid soil near of Khartoum in Sudan.

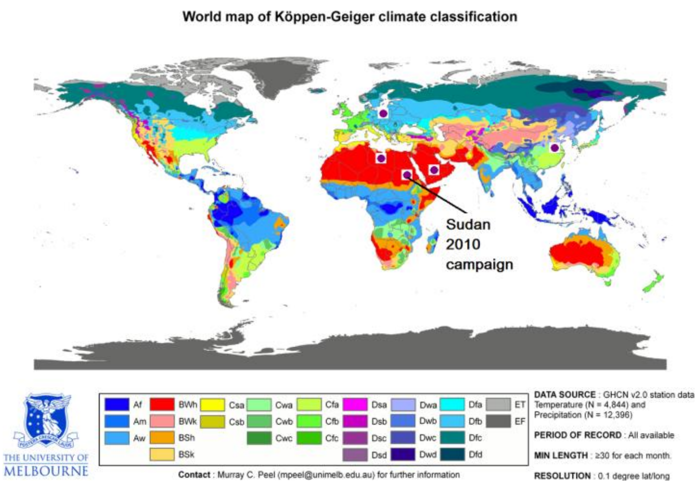

Figure.1. World map of climate classification according to Koppen-Geiger [1], ● -locations of field corrosion tests carried out by Galmar company.

II. Methodology of Field Tests

A. General

During the 2010 corrosion test campaign in Sudan have been carefully controlled temporal changes of following parameters, which have substantial influence on soil corrosion process of steel electrodes:

- Soil and air temperature,
- Air humidity,
- Soil resistivity,
- Electrochemical potential in soil in the vicinity of earth electrodes of grounded power transmission towers.

Additional tests have been made to find out specific soil properties in sites where the earth electrodes were embedded. From two sites it has been collected samples of soil, each having volume of app. 1 dl and some chemical analyses have been done to find out their chemical components. These tests have been performed at Warsaw University of Technology.

B. Measurement methodes and procedures

All field measurements have been done in the vicinity of the tower no. 31 of 220 kV transmission line "Al-Gaili to Shendi" (Fig.2).

a)

b)

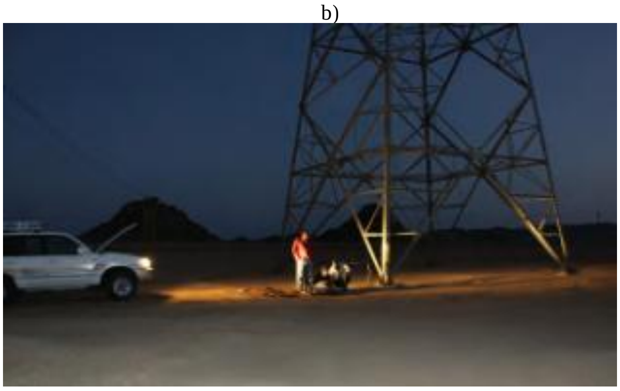

Figure 2. General view (a) and tower nr 31 (b) at investigated site.

The soil resistivity was measured in close distance from the tower using four electrodes (Wenner) method and meter Megger as shown in Fig.3. The distances between electrodes were varying from 1 to 3 m.

The soil and air temperature and air humidity have been measured using the digital multimeter (Fig.4).

The electrochemical potential was measured using the setup consisting of digital milivoltmeter and reference electrode made of copper sulphate. The configuration of the electrochemical potential measurement system is shown in Fig. 5 and 6 [3].

Figure3. Measurement of soil resistivity in the vicinity of the tower no. 31.

Figure 4. Measurement of temperature of the soil – the reading was 63,9° C.

a)

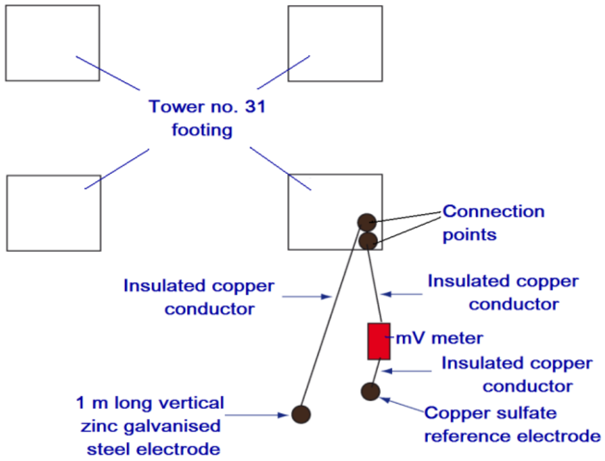

Figure 5. Lay-out of electrochemical potential measurement system.

Figure 6. Picture of electrochemical potential measurements.

The soil samples have been taken from the site and two types of chemical analyses have been performed in the laboratory with the aim to describe some physical properties and specific ions identification of soil.

First analyse was done preparing solution of 200 g of soil in 200 cm^3 distilled water, which was mixed continuously for 24 h. Then after filtering undissolved elements pH and conductivity of water extract were measured.

It was also performed qualitative analysis to identify ions in the water extract as well after treating the samples with the solution of HCl and concentrated HCl (hydrochloric acid).

III. Test Results

1. During the corrosion field test campaign in investigated site in Sudan in 2010 the soil resistivity was varying in range of 300 – 750 Ω·m in depth of 1- 3 m below the ground surface.

2. The results of continuous and simulteanous measurements of soil and air temperature, air humidity and electrochemical potential performed at investigated site in Sudan on March 3rd 2010 are shown in Fig.7. There have been observed very high variation of each climatic parameter during daytime while the electrochemical potential changes were relatively slow decreasing accordingly to the increase of soil and air temperature.

It should be noticed that the night temperatures of air and soil are much more lower than during the daytime and during the time of campaign in investigated site were not higher than few centigrades of Celsius.

3. The physical and chemical properties of soil samples taken from the investigated site are shown in Table 1. High concentration of Ca^{2+} and Fe^{3} ions indicates presence of carbonate of lime and carbonate of iron in the soil.

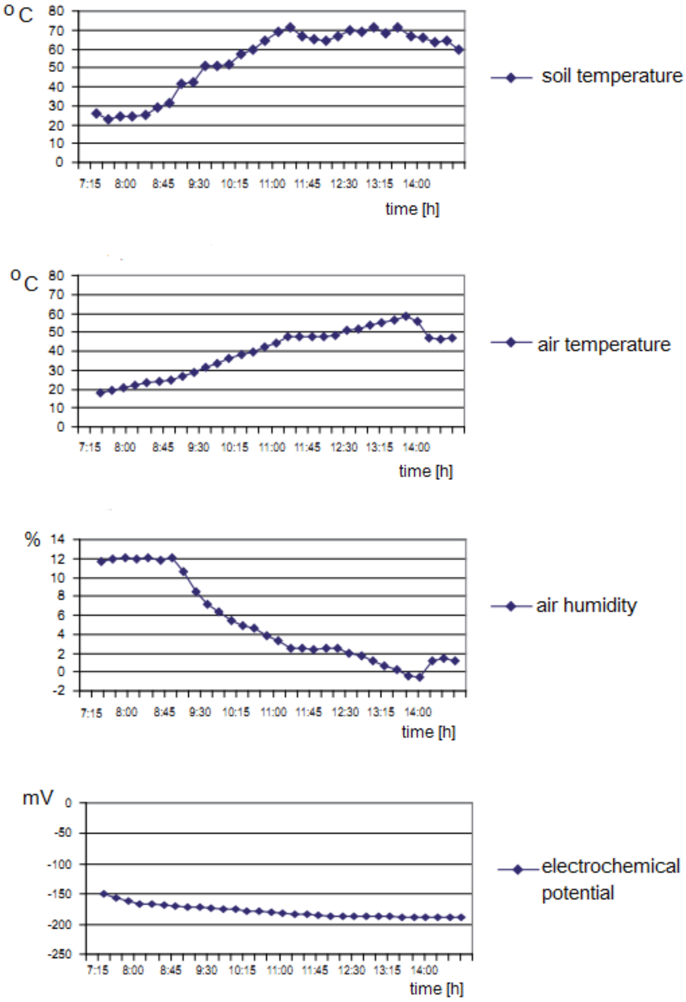

Figure 7. The results of continuous and simulteanous measurements of soil and air temperature, relative air humidity and electrochemical potential.

TABLE I. Parameters of Soil Samples

Parameter	Value and unit/comment	
Soil resitivity	300 – 750	Ω·m
pH	6,0	-
Conductivity of water extract	3,3	mS
Ions	Cl^-	Reaction with $AgNO_3$
	Fe^{3+}	Reaction with NH_4SCN
	Na^+	Small quantity
	Ca^{2+} and Fe^{3}	High concentration

IV . Examples of Earth Electrodes Corrosion

Except measurements it was done visual observation of individual elements of earthing system of 110 and 220 kV transmission line. It required excavations of earthing system components of the individual towers of the line, which were after that carefully inspected.

Typical examples of zinc galvanized steel corroded elements imbedded in soil are shown in Fig. 8,9 and 10.

Figure 8. Part of round zinc galvanized steel earth conductor after 6 months service (partially embedded in soil).

Figure 9. Part of solid zinc galvanized steel tape creating the ring earth electrode around the 220 kV transmission line tower foot after 4 years service in soil.

IV . Summary and Conclusions

In this paper were evaluated several specific parameters which play substantial role in corrosion process of zinc galvanised steel electrodes in different climatic conditions.

Figure 10. Part of solid zinc galvanized steel tape of the 110 kV transmission line tower earth electrode after 6 years service in soil.

From previous investigations performed by the authors [2] it was found that in the humid continental climate (i.e. Poland) as well in the humid subtropical climate (i.e. Jiangxi province in China) on the corrosion process and its rate of steel galvanized earth electrodes play dominant role except the atmospheric conditions (air humidity and air temperature) also the soil resistivity. I.e. in Poland where soil resistivity was varying in the range 70 – 150 Ω·m and air relative humidity was app. 40% the estimated average corrosion rate of steel galvanised rods was of 5-6 μm per year.

In China, where the soil resistivity was app. 700 Ω·m and relative air humidity 55%, the degradation of the zinc galvanized steel tape earth electrode caused the reduction of tape thickness from 4 to 1 mm during the 10 year long service period.

In the case of earth electrodes performance in Sudan - soil resistivity in the range from 300 to 750 ohm and air humidity near the ground surface close to 0% during the daytime - it was found out that for these commonly considered as favorable from point of view of protection against corrosion conditions the galvanized tape after 4and 6 years almost completely corroded (Fig.9 and 10).

When analyzing the zinc coated steel earth electrodes performance in Sudan one can assume that there is possible the occurrence of the mechanism causing the change of the electrochemical potential of zinc coating to the potential of bare steel (steel becomes the anode). It is the effect of a very high air and soil temperature increase and daily changes. They can play role as an additional catalyst increasing the intensity of corrosion process in soil and influencing the significant increase of its rate The higher changes of soil temperature of the faster is the higher corrosion intensity of galvanized steel earth electrodes embedded in soil.

As the final statement it should be emphasized that the severity of galvanized earth electrodes corrosion in different climate zones, it is observed the significant dependence of corrosion rate with a maximum air and soil temperature.

Since zinc is amphoteric groundbed in soil it will always be undergone corrosion, but at different rates. At temperatures of above 60 °C zinc changes its electrochemical potential which becames similar to the steel potential, which causes that it becomes the anode and accelerates the corrosion of steel [5, 6].

Those effects are not currently introduced to the requirements of product standards for lightning protection earth electrodes and conductors [7].

The authors suggest to consider to introduce the recommendations for corrosion tests of buried in soil LPS components introducing the factors taking into account the influence of climatic conditions, such as soil resistivity (or water content in the soil) and the temperature changes adequate to different regional climate conditions.

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