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Studiu comparativ privind coroziunea în timp a electrozilor în sol, Partea 4 – Predicția matematică și prototip

Comparative study regarding corrosion in time of the ground electrodes, Part 4 – Mathematical prediction and prototype

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Rezumat*:Obiectivul lucrării este de a prezenta, aspecte referitoare la: coroziunea metalelor acoperite şi neacoperite cu zinc în solul oraşului Timişoara (electrozi de împământare a Instalaţiei de Legare la Pamânt aferentă Instalaţiilor Electrice din Construcţii), analiza parametrilor de sol, prototipuri de electrozi, măsurători electrice, microbiologice şi analiza de prognoză-predicţie matematică, materiale şi dicţionare de termeni aferenţi. Un alt aspect prezentat în acest material este efectuarea de măsurători ale spectrului câmpului elecromagnetic oscilografiat al elementelor de metal acoperite şi neacoperite cu zinc din sol.*
Cuvinte cheie*: coroziune, electrod de împământare, sol, legare la pământ, microbiologia solului*

Abstract: *The objective of this paper is to present aspects related to: corrosion of metals covered, and not covered with zinc in the soil of Timişoara (grounding electrodes of a grounding installation related to Electrical Installations of Constructions), analysis of soil parameters, prototype electrodes, electrical, microbiological analysis and mathematical prognosis analysis-prediction, materials, and dictionaries of related terms. Another aspect presented in this material are the measurements related to the spectrum of the oscillograph electromagnetic field of the grounding electrodes, which are covered, and not covered with zinc.*

Key words*: corrosion, ground electrode, soil, grounding, soil microbiology*

1. Mathematical prediction

Dictionary of terms:

Holt-Winters Method [1, 2] Exponential smoothing methods. Smoothing techniques are used to generate smoothed values (attenuation of random fluctuations in the data from which the random component was removed) and to obtain predictions. The simple moving average method assigns equal weights (1 / k) to all k points. But recent observations provide more relevant information than past observations. So a weighting scheme that assigns decreasing weights to more distant observations would be useful. Exponential smoothing methods assign higher weights to recent observations and they decrease exponentially as they become more distant. These methods are effective when the parameters describing the time series slowly change over time.
Covariance [3, 2] In probability theory and statistics, covariance is the measure of the common variation of two random variables [4]. If the high values of one variable generally correspond to the high values of the other variable, and if the same is true for the small values (i.e. the two variables have similar behaviors), the covariance is positive [5]. On the other hand, if the high values of one variable generally correspond to the low values of the other variable (i.e. the two variables have opposite behaviors), the covariance is negative. Therefore, the covariance sign shows the direction of the linear relationship between the two variables. The magnitude of the covariance is not easy to interpret because it is not normalized and therefore depends on the magnitude of the variables. However, the normalized version of covariance, the correlation coefficient, can show by magnitude the power of the linear relationship**.**
Correlation [6, 2] In statistics, dependency is a statistical relationship between two random variables or two sets of data. The correlation refers to a wide class of statistical relationships involving dependence. Familiar examples of dependent phenomena include correlations between the physical stature of parents and their children, as well as correlations between the demand curve of a product and its price. For the study of the dependence between two variables, each of them being subjected to a random scattering, methods of correlation analysis are applied. The correlation analysis studies the average law of behavior of each of the variables according to the values of the other variable, as well as the measure of the dependence between the considered variables. Attaching to each value of one of the variables, for example of x by which the independent variable is denoted, the average of the corresponding values of the other variable, denoted y, we obtain pairs of values (x, y), which in a graphical representation in Cartesian coordinates appear in the form of a multitude of dots. This graphical representation is called the scatter plot (en plot). The correlation / dispersion diagram graphically illustrates pairs of numerical data, with one variable on each axis, observed within a common phenomenon, in order to identify the links (relationships) that are established between them [4]. If the variables are in correlation, the points will follow a line or a curve. The correlation diagram is one of the seven classic tools of quality management.
Predictive analysis [2, 7]. Predictive analysis includes a variety of statistical techniques from data extraction, predictive modeling and machine learning, which analyze current and historical facts to make predictions about future or otherwise unknown events.

Voltage prediction at sample no. 1, because the data are few, the only prediction that can be made is by trend, using the Holt-Winters method (exponential smoothing). So the series of observations:

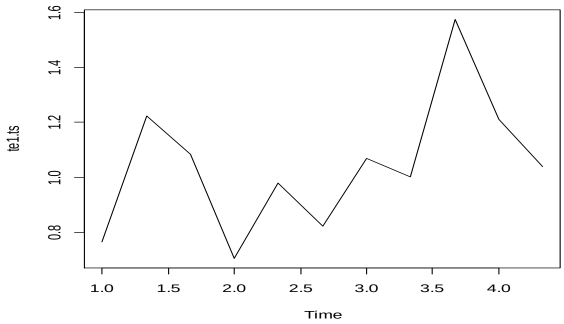

Fig. 1 The series of observations, on the components of the time series

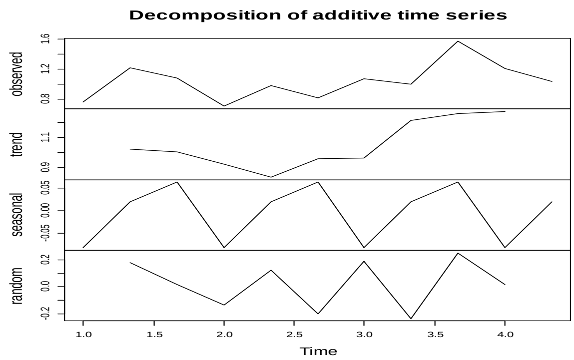

Fig. 2 Holt-Winters analysis (the first graph of the four is the trend)

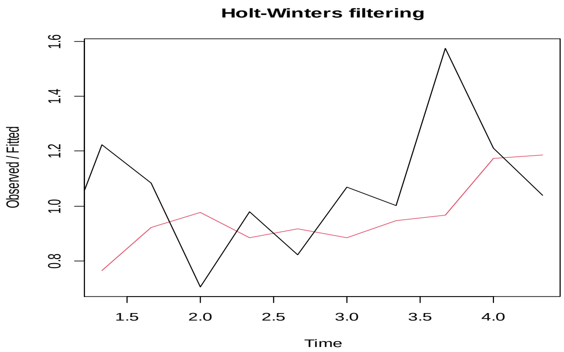

Fig. 3 Holt-Winters analysis (the first graph of the four is the trend)

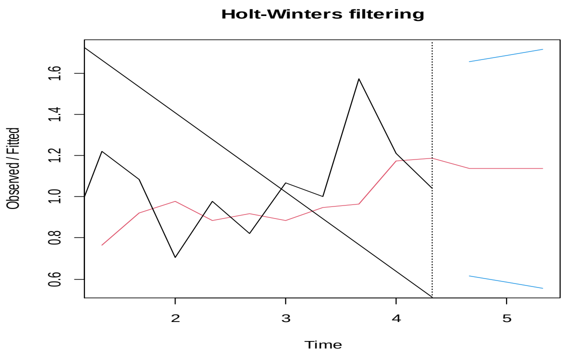

Fig. 4 Holt-Winters prediction (with limits)

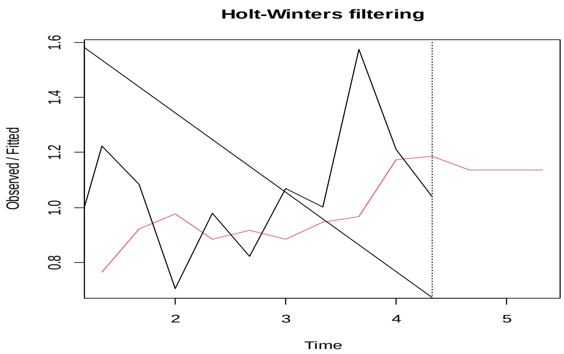

Fig. 5 Holt-Winters prediction (without max and min limits)

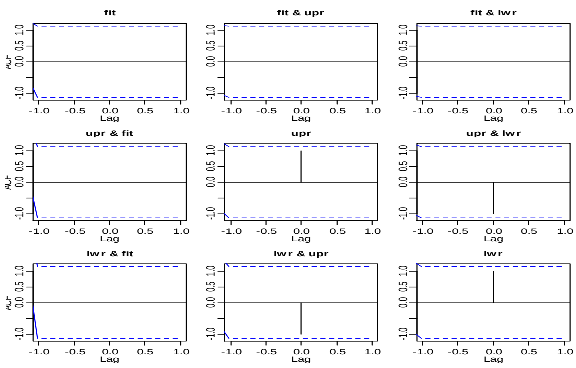

Fig. 6 Study of errors by spectral analysis (autocovariance spectrum)

Prediction for the electrical potential of the sample electrode nr. 1

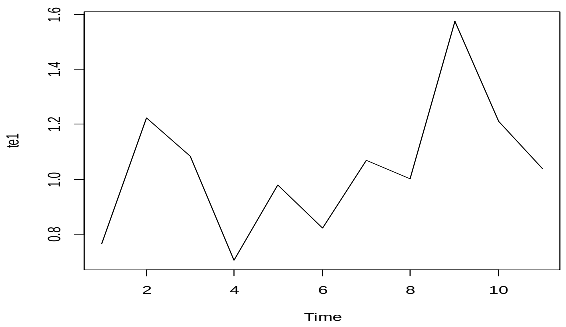

Fig. 7 The series of observations

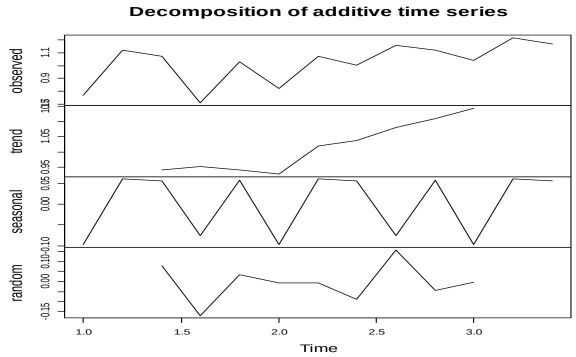

Fig. 8
Series decomposition, first graph = observed series, second graph-trend, third graph = seasonality, fourth graph = random errors

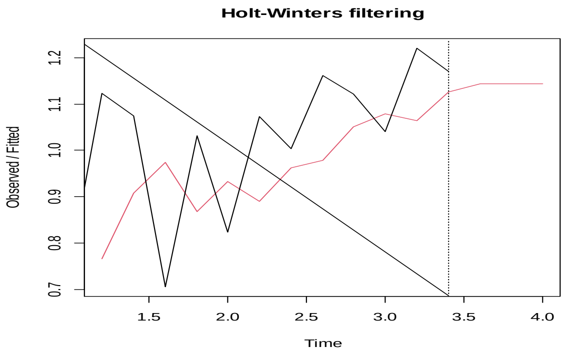

Fig. 9 Tension and prediction by the Holt-Winters method

Correlation meta-analysis *(meta-analysis is an analysis of several studies, in our case on several samples-electrodes)*

1.1. ***Correlation*** between tension and current

Five electrode samples were analyzed marked “e1”, “e2”, “e3”, “e4”, “e6” (electrode e5 was excluded because we do not have data on conductivity). 11 data were analyzed (at voltage there were 12 but at current 11, we eliminated the first value from voltage). Graphically we have the following:

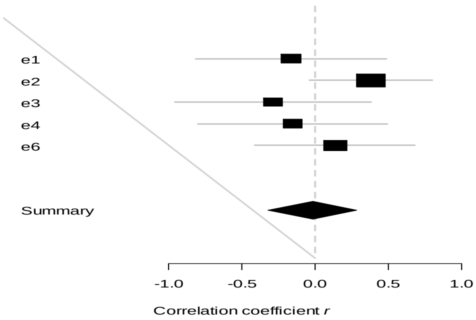

Fig. 10 It can be seen that at: e1, e3, e4 the correlation is slightly negative while at e2 and e6 is slightly positive. These values are the result of a random effect, the fixed effect being close to zero. In conclusion there is a weak correlation (connection) voltage and current, with different effects. For predictive purposes, it is recommended to analyze voltage and current separately. It can be seen that the electrodes e1, e3 and e4 can be analyzed jointly and analogously for e2 and e6.

1.2. **Correlations between voltage and conductivity**

Graphically we have the following:

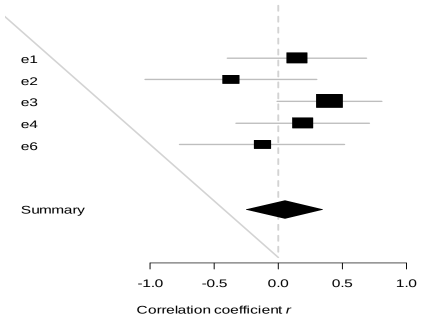

Fig. 11 A positive correlation is observed at: e1, e3 and e4, and at the other two the correlation is negative. The effect is random, the fixed effect being slightly positive. There is not a great correlation between voltage and conductivity, at least the linear connection is not supported from a statistical point of view. It is observed that the electrodes e1, e3 and e4 can be analyzed unitarily and analogously e2 and 26.

1.3. Correlations between current and conductivity

Graphically we have the following:

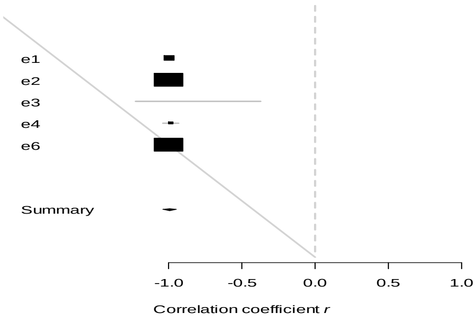

Fig. 12

It is observed that at all 5 electrodes the correlation is about the same, negative close to -1, so an inverse relationship between current and conductivity. In conclusion, the inverse linear connection is statistically supported for all 5 electrodes, as such it is sufficient to make a predictive at the current level and the conductivity is obtained immediately by an inverse linear relationship, co = a + b * with, b <0. It is sufficient to perform the analysis at a single electrode (e2).

1.4. Correlations between resistance and resistivity

The electrode resistance appears in relation to the ground resistivity for the 6 electrodes, having only 4 measured values.
Graphically we have the following:

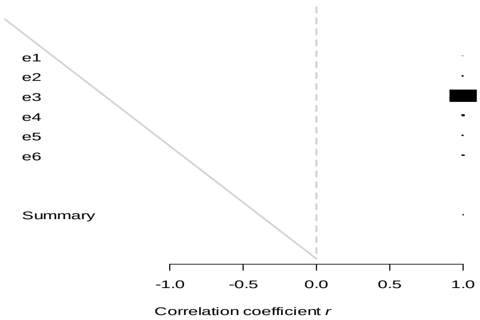

Fig. 13

There is a positive relationship at all 6 electrodes close to 1, so a direct relationship between the 2 quantities. If the e5 electrode is removed from the analysis, we have (similar relationship)

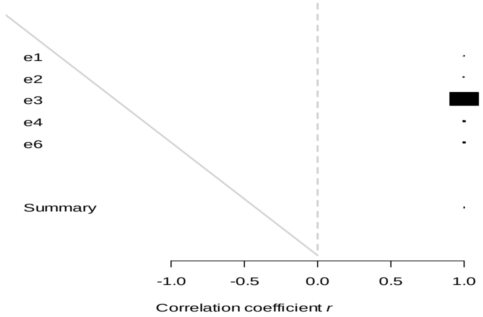

Fig. 14
If the electrode e5 is removed from the analysis, we have (similar relationship). In conclusion, it is enough to know only one quantity, the other is obtained immediately by a direct linear relation of the type rev = a + b * rez, b> 0. It is sufficient to make the prediction at a single electrode (preferably e3).

In conclusion, a predictive of voltage and current on e1 (or e3, or e5) and separated on e2 (or e6) is recommended. Conductivity can be obtained from current prediction. Also, a resistance predictor can be made on only one electrode, or it can be obtained directly if the resistivity is known.

Discussions and conclusions

2. Prototypes

Prototype for remote monitoring of soil corrosion of zinc coated and non - zinc coated metal elements [28]

The technical problem that the prototype solves consists in the realization of an installation for real-time remote monitoring of the corrosion in the ground of the metallic elements covered and not covered with zinc at predetermined depths and the recording, transmission and archiving of the obtained data. The installation for remote monitoring of corrosion in soil of metal elements covered and not covered with zinc according to the prototype consists of a set of metal tubes covered with zinc (of predetermined thicknesses) and not covered with zinc, alternately positioned vertically in the ground at depths predetermined, provided at a certain distance, in parallel, with PVC tubes equipped with elements with electrical conductivity and sensors for measuring temperature and humidity both in the ground and above ground. The entire assembly is connected to a distribution box and a power source powers the control of a remote relay, a microcontroller and a server connected to the internet. The electrical connections downstream of: air and ground temperature and humidity sensors, zinc-coated and non-zinc-coated metal tubes and PVC tubes with electrically conductive elements are connected to the distribution box which is in turn connected to a microcontroller with

HDMI port for a monitor and USB for storing data in CSV format. The microcontroller automatically runs a program designed to record values from elements with electrical conductivity, humidity, and temperature at regular intervals of one second, values that can be viewed on the monitor and stored on the CSV data storage device for processing and analyzed. At the same time, the data recorded from the microcontroller are transmitted to a server where they are processed and stored in a database, "noSQL". The communication with the database is done through a Rest Api interface that also offers a graphical interface accessible to an internet address. The microcontroller and server are connected to the router.

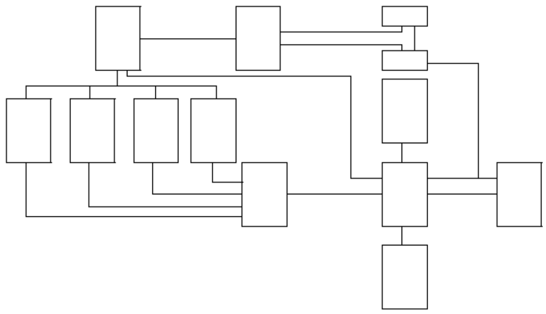

Fig. 15 Schematic diagram of the installation prototype

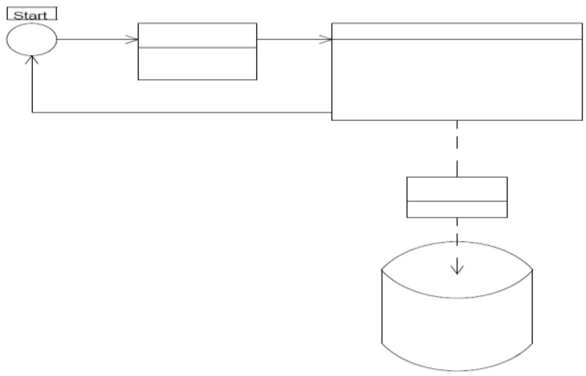

Fig. 16 Schematic of the installation prototype software

BUILDING EARTH ELECTRODE WITH CORROSION RESISTANT CONNECTIONS [9]

The prototype refers to a grounding electrode provided with an anti-corrosion device at the horizontal connection used for the human protection installation against accidental contact voltages in the electrical protection installation of constructions against the effects of lightning. The construction ground electrode with corrosion-resistant connections according to the prototype is connected by welded connections to the (flat strip) of the horizontal part of the construction ground installation. The electrode consists of concentric tubes, an outer galvanized steel tube and an inner galvanized steel tube joined at the bottom by welding with a flat strip, and at the top by a flat strip with elongated wings and configured in an "S" shape. , so that through the ends of the flat strip to make the connections by welding with the flat strip of the horizontal earthing installation. The connections are coated with bitumen inside corrosion-resistant plastic containers and the upper part of the electrode assembly thus made, respectively the area of the connections between the electrode plate and the horizontal grounding plate is arranged in a visiting room with access for periodic checks and measurements. The outer galvanized steel tube provides at the bottom, on a limited length, at least 4 equidistant longitudinal notches to allow the reflection of the tube material so that on the said tube materialize, transversely on its axis some wings, in the form of a rosette, which defines a larger contact surface of the galvanized steel tube with the ground. The grounding electrode of constructions with corrosion-resistant connections has the following advantages:

- allows better contact with the ground;
- ensures, through a lower electrical resistance, a better passage and dissipation of the lightning overvoltage through the ground;
- ensures the corrosion protection at the joint parts for the flat strip of the horizontal earthing installation;
- ensures a simpler assembly work so that the possibility of friction with the ground is eliminated, implicitly the loss of a zinc microlayer that covers the electrode.

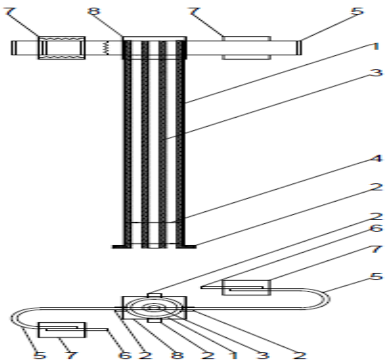

Fig. 17 General diagram of the earth electrode with low electrical resistance and anti-corrosion device

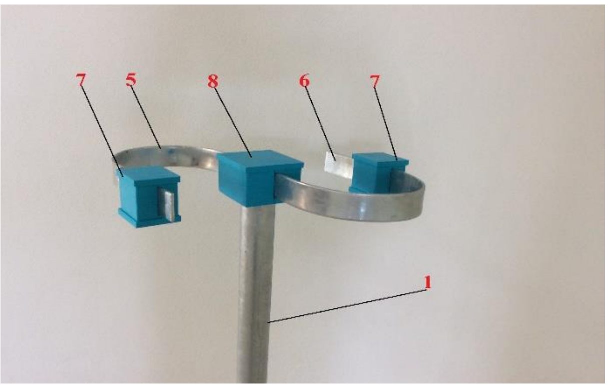

Fig. 18 Imagine foto cu electrodul destinat ILP, prevăzut cu dispozitiv anticoroziune la conexiune;

Fig. 19
Corrosion at the joint area with, weld bead (unprotected) between the vertical and horizontal electrode intended for ILP

Fig. 20
Corrosion-resistant joints with nut (bolt with nut) on the flat band (40X4) of Ol Zn unprotected anticorrosive, intended for ILP

Fig. 21
Corrosion trace joints (contact piece between electrode and round Ol Zn profile) for ILP)

Fig. 22
Joints with corrosion marks (nut screw) on the Ol Zn flat strip for ILP

Fig. 23
Bitumen container in the connection area of the horizontal electrode (OL Zn flat strip) for ILP

Fig. 24
Bitumen container in the connection area of the horizontal electrode (OL Zn flat strip) for ILP

It should be mentioned that this type of electrode intended for Grounding Installations, is mounted in the ground in a vertical position after the horizontal trench has been made at the predetermined depth of the norm (the trench is intended for galvanized flat strip of length according to a calculation of ILP - Installation Grounding) the next step being to make penetrations in the ground with the drill (hydraulically or mechanically actuated) at the preset depth of the electrode. The number of electrodes intended for ILP must correspond to that mentioned in the calculation of the ILP related to the dispersion resistance of the earthing.

Example:

Table 1

Calculation example for a grounding installation

Number of electrods OL Zn, L=1.5m	15 buc.
Strip OL Zn, 40X4mm cu L=45m	1 buc.
Soil electrical resistivity (clay)	80 Ωm
Dispersion resistance	0.97Ω
Calculation formula	$R= 0.366\frac{\rho}{l}lg\frac{4l}{d}$

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