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Optimization algorithms for estimation of the main soil corrosion factors

1. Introduction

The total length of oil pipelines in Russia is about 200 thousand kilometers, and the entire pipeline Park currently exceeds thirty years of operation. In conditions when more than one third of failures in pipelines are caused by corrosion, the problem of anticorrosive protection has become crucial and is considered by researchers and exploiters. One of the main ways to extend the service life is electrochemical protection (EP) [4]. Since new EP efficiency control means have been developed, the problem of collected data systematization and developing methods and algorithms of EP optimization is becoming essential.

To estimate the main soil corrosion factors and EP effectiveness the hardware-software complex «KORTES» was developed in the Electroanalysis and corrosion monitoring research laboratory in Tomsk Polytechnic University. This complex allows measuring EP parameters, such as cathodic protection current, polarization potential and the total potential, as well as the parameters of the soil corrosion activity, such as soil resistivity (SR) and the hydrogen index value of the soil (pH) on the basis of the potential fall curve processing using the potentiometric analysis method.

Potentiometric analysis methods have been known since the end of the last century. Intensive development of potentiometry in recent years is caused predominately by emergence of various types of ion-selective electrodes allowing conducting direct determination of the concentrations of many ions in solution, and by success achieved in design and mass production of devices for potentiometry measurements [3].

Potentiometric analysis methods are sub-divided into direct potentiometry (ionometry) and potentiometric titration. Methods of direct potentiometry are based on direct application of the Nernst equation to figure out the activity or concentration of the electrode reaction participant by experimentally measured electromotive force (EMF) of the circuit or by the related electrode potential.

2. Application of the Nernst equation for dry mixtures

In other words, the Nernst equation is used to calculate the parameters of the soil corrosion activity. This equation relates thermodynamics with electrochemical theory and it is used to solve the problems concerning diluted solutions only [1]. In a general form this equation can be written as

$$E = E^0 + \frac{RT}{nF} \ln \frac{a_{Ox}}{a_{Red}},$$

where

- E is an electrode potential;
- E^0 is a standard electrode potential measured in volts;
- R is a universal gas constant;

- T is absolute temperature;
- F is the Faraday constant;
- n is the number of moles of electrons involved in the process;

- a_{Ox} and a_{Red} are the activities of the oxidized and reduced forms of the substance involved in semi-reaction, respectively.

If simplify the Nernst equation substituting R and F constants numerical values and translating from the natural logarithm to the decimal one, at $T = 298$ K it will be written as

$$E = E^0 + \frac{0,059}{n} \lg \frac{a_{Ox}}{a_{Red}}$$
.

This equation is conventionally considered to be applicable to solutions, but in case of using comparison electrodes without-electrolyte and the sensor based on porous steel the Nernst method of solution activity determination can be applied to dry mixtures [2].

Thus, it becomes possible to define the soil chemical activity without complex procedures including sampling and subsequent analysis in laboratory conditions. To evaluate the soil chemical activity only one device is required. This device allows regulating the redox processes and recording changes of the electrode potential.

3. Implementation of the Nernst equation in the hardware-software complex "KORTES".

This method is implemented with the following algorithm:

1. Current is supplied to the sensor; it activates the process of hydrogen ions accumulation in porous steel.

2. When the current supply is interrupted, the number of hydrogen ions starts to decrease gradually to the normal level.

3. The device measures the decline of the electrode potential to the normal level.

4. The set of data is processed by the program.

5. The curve of the potential fall is smoothed by method of moving average to obtain a smooth curve. The most sustainable part of the averaged curve is an inflection point (Fig. 1).
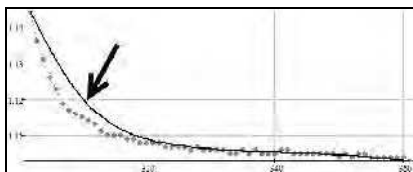

Fig. 1. Curve of the potential fall, the inflection point is shown with the arrow

6. The inflection point is determined by the search for the global maximum of the second derivative. The maximum is of a peak shape, since the potential fall is of an exponential shape (Fig. 2).
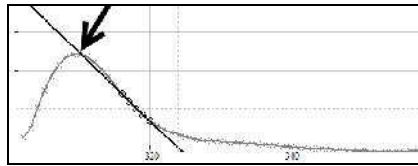
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Fig. 2. The second derivative of the inflection point curve

7. At half of the peak curve the tangent is plotted. This tangent defines the tendency of peak to fall.

8. The intersection of the tangent with a zero is calculated. This point can be considered as the beginning of the quasilinear curve part.

9. A linear trend is plotted along the curve part from the point found to the quasilinear part.

10. The trend value at the measurement starting point will be the desired value of potential (Fig. 3).
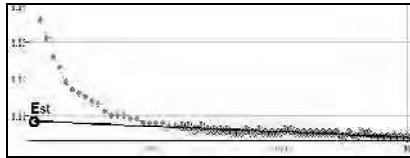

Fig. 3. Trend plotted along the quasilinear curve part, **Est** is desired value of the potential

11. The hydrogen index value of the soil can be calculated with this value obtained by the Nernst equation.

In this algorithm, the definition of the hydrogen ions saturation moment of the porous steel is problematical since it depends on many properties of the investigated soil.

4. Optimization algorithm for evaluation of the hydrogen index value of the soil.

To determine the hydrogen ions saturation level of the porous steel the following algorithm was applied:

1. The device sets the current which is obviously more than the working current for a short period of time.

2. When the current decreases to the working level, the device records the curve of the electrode potential for the analysis.

3. The stationarity of the potential curve is checked by estimating standard deviation.

4. If the estimate meets the criteria for stationarity with the specified accuracy, the device stops the process of hydrogen ions accumulation and switches to measurement. Otherwise, the process repeats the cycle of item 1.

This algorithm is more effective than the process stationarity assessment, since the excess current at the beginning of each of the iterations reduces the time of porous steel saturation by hydrogen ions several times as much.

5. Conclusion

The algorithm of determination the hydrogen ions saturation level makes possible to standardize the assessment methods of the soil pH level and soil resistivity, to simplify and speed up the preparation of the device to measurement, and to reduce the subjective factors influence on the measurement conducted.

Wide application of these methods in the devices for estimation of the soil corrosion activity and the effectiveness of the cathodic protection equipment will reduce labour and material costs on the diagnosis and maintenance of the pipelines, identify areas of the corrosion risk and develop recommendations for additional preventive measures to protect the pipelines.

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Hardware and software implementation of telecommunication systems components

Hardware implementation of telecommunication systems components is currently considered to be of great interest for researchers and developers since this implementation can be faster than software implementation. Nevertheless, software implementation sometimes can be more flexible and easily debugged. Note that numerous telecommunication components are implemented in the form of "hard" logic, and hardware implementation of high level telecommunication protocols is being investigated. Therefore, clear criteria to evaluate the effectiveness of hardware implementation versus software one. In this paper, the criteria selected are time and speed of input data processing. The preliminary results of evaluating the effectiveness of hardware implementation as the components of the telecommunication system are shown.

In particular, since security of information transmitted over communication channels is of current importance in today's world, the paper examines the possibility of hardware encryption. U.S. Standard DES is chosen as an encryption algorithm.