

# Method of forming means for monitoring the process of electrochemical protection of pipeline systems

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**Abstract.** The current issue of ensuring the quality of electrochemical protection processes by developing and selecting options for the location of control, measuring and automation equipment for multiparameter and multichannel systems using pipelines as an example is considered in the article. The possibility of use the Mahalanobis-Taguchi provisions, as well as the Mahalanobis metric, to select the basic version of the location of monitoring facilities is described. The stages of diagnostics of possible options for the location of control, measurement and automation equipment for pipeline systems are determined.

## 1. Introduction

When considering the features of the control, measurement and automation of the process of electrochemical protection of pipelines as a complex system, its cost and quality, it is necessary to approach problems from system positions. This will reduce the number of problems at the beginning of design, reduce costs at all stages of the life cycle, including warranty service.

The quality and efficiency of the process of electrochemical protection of pipelines, primarily are determined by the technical level and the actual technical state of the used monitoring tools for the process of electrochemical protection of pipelines. The failure of the means of monitoring the process of electrochemical protection of pipelines cannot be compensated by the perfect means of processing information. Along with this, even a partial decrease in the operability of the means for monitoring the process of electrochemical protection and the resulting errors will lead to a reduction not only in the quality of the process of electrochemical protection of pipelines, but also in other technical systems associated with pipelines, down to complete failure. Such consequences should be parried through careful circuit engineering, design and technological development based on the system approach and the use of modern quality assurance methods. Using modern terminology, the means of monitoring the process of electrochemical protection of pipelines should have the properties of robustness. this requirement involves the use of a systematic methodology for ensuring the operational stability of the electrochemical protection process in the early stages of the life cycle, namely, when choosing the concept of constructing monitoring aids, during their circuit design, design and technological design, and during the production process of the system elements, taking into account the use of active control. In this case, the issues of ensuring the quality of the process of electrochemical protection of



pipelines, which can be solved today by using modern methods of quality assurance, are becoming topical. [1-4]

## 2. The main provisions

With regard to the task of ensuring the quality of the process of electrochemical protection, the choice of the location of the means for monitoring the process of electrochemical protection, the application of a single criterion distorts the meaning of the problem and can lead to incorrect conclusions due to the preference of one quality indicator to another. The need for such an approach, for example, arises in the selection of options for implementing monitoring tools for the process of electrochemical protection, while requiring the simultaneous provision of characteristics in terms of accuracy, cost and speed. [5-6, 9]

For the monitoring of the process of electrochemical protection, which are multiparameter and multichannel systems, the integral quality criterion is formed on the basis of a set of local criteria, with the priority criterion being the condition for achieving cathodic protection, according to which the value of the polarization potential must be within

$$\varphi_{\min} \leq \varphi(t_i) \leq \varphi_{\max}, \quad (1)$$

where  $\varphi_{\min} = -1.15 B$ ,  $\varphi_{\max} = -0.85 B$ ,

wherein

$$\int_0^T x(t) dt \rightarrow \min, \quad (2)$$

$$\frac{dx}{dt} = \frac{k}{\varphi(t)}, x(0) = 0, x(T) = x_T$$

where  $x(t)$  - corrosion condition of pipelines,  $T$  - control cycle period,  $x_T$  - maximum cavern depth.

For the automated maintenance of current values of electrochemical protection installations in the range of optimum values, it is necessary to know the distribution of the polarization potential under the action of the currents of the anode ground loops. The basis for the design of means for monitoring the process of electrochemical protection of pipelines from corrosion are mathematical models of the process of electrochemical protection of pipelines. [5-7]

The processes of corrosion in the conditions of electrochemical protection are very complex and consist of several interconnected by the total value of the electrode potential of electrochemical reactions. Their kinetics depends on a significant number of factors. Effective selection of parameters of the process of electrochemical protection is impossible without the analysis of electric fields and without knowledge of the regularities of distribution of the controlled potential and current density. It is especially important to take into account the regularities of the change in the polarization potential from the control current density, as well as the geometric parameters and mutual arrangement of pipelines of finite dimensions when solving the problems of placing monitoring aids and selecting their parameters.

For pipelines of urban conditions, complex schemes of mutual arrangement are possible. Therefore, for an effective process of electrochemical protection of pipelines, it is advisable to use mathematical models, the scope of which applies to cases of arbitrary mutual arrangement of pipelines, geometric parameters of pipelines of finite dimensions, nonlinear dependence of the polarization potential on the control current density, the end points for connecting the means of monitoring the process of electrochemical protection, protection of pipelines against each other. [5-8]

The assessment of the peculiarities of the location of the means for monitoring the process of electrochemical protection, their cost and quality is a systemic problem, and the sufficient technical level of the developed options for monitoring electrochemical protection monitoring equipment can be

confirmed only after their resistance to possible destabilizing factors is demonstrated. To select the basic option for the location of monitoring facilities for the process of electrochemical protection, it is proposed to use the Mahalanobis-Taguchi positions among several alternatives. To further optimize the parameters of the basic version of the electrochemical protection monitoring facility by reducing the measured variations in technical characteristics, assuming that these technical characteristics are adjusted to the target value, a robust design methodology should be applied that allows for cost limitation based on the Mahalanobis metric by the selected local criterion.

For each alternative arrangement of means for monitoring the process of electrochemical protection based on mathematical models, the electrochemical protection process is simulated. The distribution of the polarization potential along the pipeline determines the minimum, maximum and average values of the polarization potential. When comparing the minimum  $\varphi_{\min}$ , maximum  $\varphi_{\max}$  and average  $\bar{\varphi}$  values of the polarization potential with the boundary values of  $\varphi_{\min} = -1,15 \text{ B}$  and  $\varphi_{\max} = -0,85 \text{ B}$ , three possible outcomes are possible (Figure 1)

When comparing suitable and conditionally suitable options for monitoring the process of electrochemical protection of pipelines, the criterion for achieving cathodic protection must be decided: how far is the specific version of the location of the monitoring tools for the process of electrochemical protection of pipelines from the baseline indicators of "suitable" means of monitoring the process of electrochemical protection of pipelines. This is done using the Mahalanobis metric.

The Mahalanobis metric  $d^2$  is calculated from the value of the multidimensional function  $x$  to the mean value of the vector  $m_x$  by the formula

$$d^2 = (x - m_x) C_x^{-1} (x - m_x)^T, \quad (3)$$

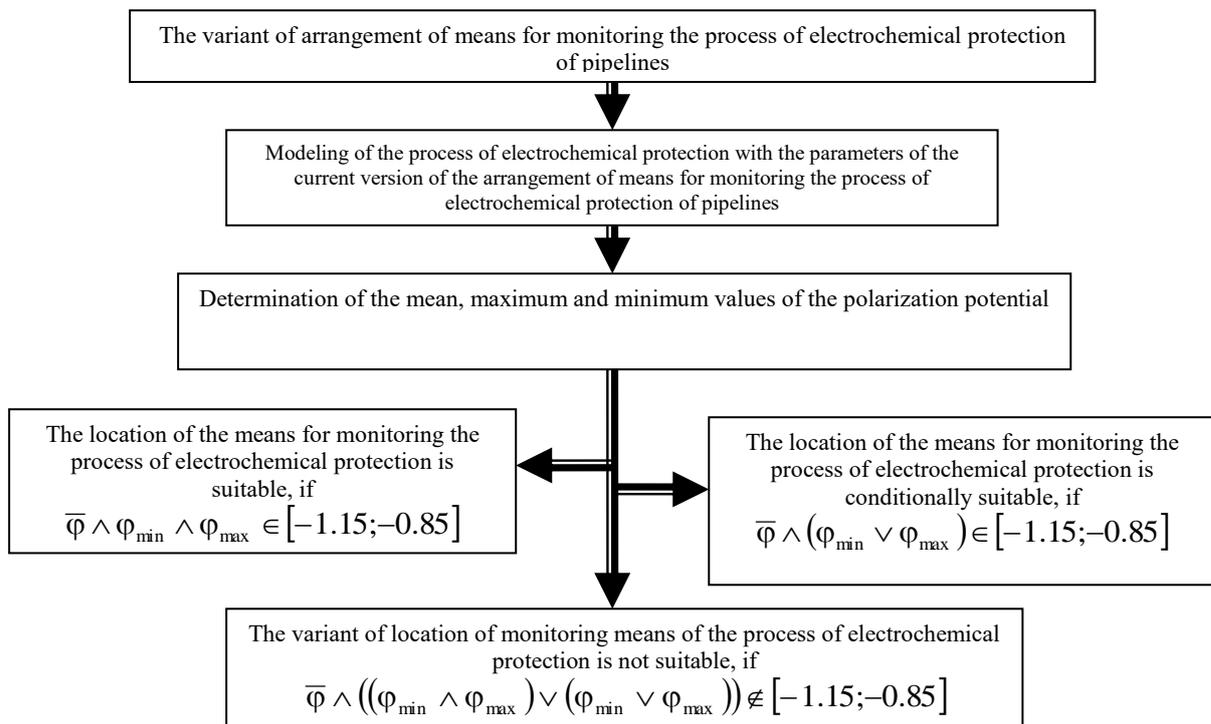
where  $x$  –  $n$ -dimension vector of the measured characteristics for this variant of the arrangement of means for monitoring the process of electrochemical protection of pipelines,

$m_x$  – mathematical expectation of the vector  $x$ , determined by the suitable options for location of monitoring tools for the process of electrochemical protection of pipelines;

$C^{-1}$  – inverse variational-covariance matrix for measured characteristics  $x$ .

Diagnostics of possible arrangements for monitoring the process of electrochemical protection of pipelines is carried out in two stages (figure 1):

- obtaining (based on the results of mathematical modeling) the current set of values of parameters of the process of electrochemical protection and comparing them with values corresponding to the permissible process of electrochemical protection of pipelines;
- an estimate of the Mahalanobis metric for a set of data corresponding to suitable and conditionally suitable options for location of monitoring tools for the process of electrochemical protection of pipelines. The variant of arrangement of monitoring means of the process of electrochemical protection of pipelines, characterized by the minimum value of the Mahalanobis metric, is considered to be the base one.



**Figure 1.** Variants of arrangement of means for monitoring the process of electrochemical protection of pipelines.

### 3. Conclusions

Applying traditional methods of processing experimental data in the absence of a priori information on the different quality of options, it is impossible to determine to which of the numerous existing categories the option of location of control, measuring and automation equipment for the process of electrochemical protection of pipelines belongs. At the same time, the Mahalanobis-Taguchi provisions are free of these shortcomings and can be effectively applied to ensure the quality of the process of electrochemical protection of pipelines at the design stage of control, measuring and automation equipment.

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