Automated process control quality improvement of technical systems electrochemical protection

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Abstract. The article deals with the issues of quality improvement at the life cycle stages of means of automated monitoring of electrochemical protection of technical systems. The possibility of production of automated control facilities with robustness properties in relation to changes in external influences and environmental conditions is considered, which improve the quality of the process of electrochemical protection of technical systems. The article considers the stages of the process of designing the means for automated control of the electrochemical protection process. A set of local criteria for the formation of an integral quality criterion for solving the problem of choosing the optimal options for the location of the means for automated control of the electrochemical protection process is determined.

1. Subject area

The quality of electrochemical protection (ECP) process and the efficiency of the application of the means for automated control of the process of ECP of technical systems (TS), primarily determined by the technical level of ECP technology and the actual technical state of the automated process control equipment used in the composition of ECP TS. The risk of occurrence of technical failures and their consequences should be reduced due to careful circuit-making, design and technological testing of means for automated control of the ECP process on the basis of the system approach. Using modern technology, the means of automated control of the ECP process must have the property of robustness.

This requirement assumes the use of a system methodology for ensuring the quality of the projected system in the early stages of the life cycle, namely, when choosing the concept of constructing means for automated control of the ECP process, during circuit, structural and technological design, as well as during the production of composite elements, taking into account the use of active control.

2. Relevance

The problem of ensuring the technical and environmental safety of potentially dangerous technical systems in connection with their aging and corrosion is also relevant in the 21st century, since their refusal can cause problems in the technosphere. Existing methods and means of monitoring the
ECPTS process are oriented to a significant number of manual operations, which leads to insufficient level of efficiency, reliability of information, quality of regulation and decisions, and does not provide automation of ECP process control.

3. The main provisions
Improving the quality of ECP TS is based on quality assurance procedures at each stage of the life cycle of ECP automated process control.

While ensuring the quality of the design phase of ECP automated process control can be divided into five stages:
- research;
- selection of the concept of construction of automated process control ECP;
- circuit engineering design;
- structural design;
- technological design.

The process of designing of ECP automated process control includes:
- the stage of structural synthesis, consisting of the definition of the list of the types of components of the automated process control equipment of the ECP process and the way they communicate with each other, the search for the optimal structure, and the corresponding mathematical model;
- parametric synthesis stage, which is to determine the numerical values of the parameters of the selected elements within the structure, and efficiency conditions on the output characteristics of ECP automated process control.

The choice of the optimal parameters of the means for automated control of the ECP process implies the solution of the following tasks:
- choose a set of parameters that satisfy the principle of constructing the projected means of automated control of the process of ECP and the requirements of the technical assignment;
- choose the parameter types according to the optimal combination;
- choose forms of parameters interaction in means of automated control of the process of ECP, based on the presence of connections, of a different physical nature between the elements.

The solution of the problem of choosing optimal in the sense of the established criteria for the location of the means for automated control of the ECP process assumes the presence of an integral indicator that most fully characterizes the main system properties of the means for automated control of the ECP process. An indicator that allows obtaining a numerical assessment of the degree of conformity of the means of automated control of the ECP process to their intended use is an integral quality criterion (IQC), which is a set of characteristics (economic, functional, information, used individually or collectively)

Modern systems theory considers means of automated control of the process of ECP as an aggregate of separate parts interconnected for the purpose. As parts of the system, depending on the described system properties, elements or individual structures of means for automated control of the ECP process are considered. Means of automated control of the ECP process are characterized by a number of essential properties that allow a quantitative evaluation of internal parameters $\Theta$, as well as sets of input $\{G\}$, output $\{\Phi\}$, control parameters $\{Z\}$ and destabilizing factors $\{X\}$.

The properties characterizing the quantitative values of the indicators of the projected facilities for automated control of the ECP process are called output characteristics

$$\Phi = (\varphi_1, \ldots, \varphi_m)^T.$$ 

The parameters of the projected means for automated control of the ECP process, which can be varied, are called control parameters. Control parameters in the design are combined into a vector

$$Z = (z_1, \ldots, z_n)^T.$$
External parameters that characterize the properties of the external environment, which in general have a random nature, are reduced to a vector of destabilizing factors

\[ X = (x_1, \ldots, x_j)^T. \]

Under the mathematical model of the projected means of automated control of the process of ECP is meant a mapping between the sets of parameters \( \{Z, X\} \) and \( \{\varphi\} \), which, in particular, can be specified in the form of functional relationships

\[ \varphi_1 = \varphi_1(z_1, \ldots, z_n; x_1, \ldots, x_j) \]

\[ \ldots \]

\[ \varphi_m = \varphi_m(z_1, \ldots, z_n; x_1, \ldots, x_j) \]

Requirements arising from the technical task, the conditions of physical and circuit realizability, the operating conditions are given in the form

\[ z_j^* \leq z_j \leq z_j^*, \quad j = 1, n, \]

\[ \varphi_i^* \leq \varphi_i(z) \leq \varphi_i^*, \quad i = 1, m. \]

In the design process, only those values of the vector \( \{Z\} \) are considered that belong to the set of admissible values of \( D \)

\[ D = \{z \mid z_j \leq z_j \leq z_j^*, \quad j = 1, n\}. \]

Any vector \( Z \in D \) is a workable version of the projected means for automated control of the ECP process. Let the projected means for automated control of the process of ECP to be described using a deterministic mathematical model \( \varphi = \varphi(z) \). If in the region \( D \) there is only one value of the vector of control parameters \( \{Z\} \), then the decision on the choice of the means for automated control of the process of ECP is uniquely determined. In cases where the workable version is not the only one, to compare the options and choose the optimal type, the criteria for optimality

\[ f = f(\varphi(z)) = f(z). \]

The extreme value of the objective function numerically characterizes the property of the technical and economic indicator of the projected means of automated control of the ECP process. The criterion shows the relative preference of one variant in relation to the other, determines the design goal and together with the vector \( \{Z\} \) and the region \( D \) forms a mathematical model for making the optimal decision, which is the task of parametric optimization

\[ f(z)^* = \min_{z \in D} f(z) \quad \text{or} \quad f(z)^* = \max_{z \in D} f(z). \]

in the case of a single-objective problem. The solution of the problem is reduced to the choice of controllable parameters \( z^* \) belonging to the admissible region and delivering an extremum to the optimality criterion \( f(z) \). In this case, the level of quality is uniquely determined only by the criterion value. The formation of a single criterion in the form of a scalar function is hampered by a number of complexities:

- an analytical description of the mutual functional dependencies of the parameters, since their identification is associated with the need to take into account the nonlinearities of characteristics and other factors;
taking into account the mutual influence of individual quality indicators, and optimization by one of some indicators may lead to the output of the other for the tolerance field.

The integral criterion for the quality of means for automated control of the ECP process should:

- to measure the main characteristic - a useful effect that allows to consider the option of the location of means for automated control of the process of ECP quality or low-quality;
- quantitatively evaluate the quality of the location of the automated process control equipment of the ECPTS process;
- consider the influence of as many parameters as possible.

With regard to the problem of ensuring the quality of the location of the means for automated monitoring of the ECP process, the use of a single IQC 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 the implementation of automated process control equipment for the process of ECP, while requiring a simultaneous, often contradictory, maintenance of accuracy, cost, and speed. If one criterion cannot be applied from a set of partial criteria, a vector criterion

The formulation of the decision-making problem in terms of multicriteria optimization is related to the question of comparing alternatives in the set of objective functions (criteria) [1-3]. For the means of automated control of the ECPTS process, which are multiparameter and multichannel systems, the IQC is formed on the basis of a set of local criteria

\[ IQC = \{ K_1, K_2, K_3, K_4, K_5 \}, \]

where \( K_1 \) - local criterion of the cathodic protection condition;
\( K_2 \) - a local criterion for the timeliness of checking the conditions of a local criterion \( K_1 \);
\( K_3 \) - local criterion of speed of means of automated control of the process of electrochemical protection;
\( K_4 \) - local criterion of limitations on total costs for the technology of electrochemical protection;
\( K_5 \) - a local criterion for the probability of failure-free operation of the means for automated monitoring of the process of electrochemical protection.

When controlling the ECP process, the local criterion \( K_1 \) is the priority, since it determines the corrosion protection, and therefore the quality of the ECP. Evaluation of the peculiarities of the location of the means for automated control of the process of ECP, their cost and quality is a systemic problem, and the sufficient technical level of the developed options for the location of means for automated control of the ECP process can be confirmed only after their resistance to possible destabilizing factors (DF) is demonstrated. At the same time, it is necessary to achieve a balance between quality and cost, for which the tolerances for the parameters should be selected, guided by the cost. To select the basic option for the location of automated process control equipment for the ECP process, it is proposed to use the Mahalanobis-Taguchi positions among several alternatives. To further optimize the parameters of the basic option for the location of automated process control equipment for ECP processes by reducing the measured variations in technical characteristics, assuming that these specifications are adjusted to the target value, it is necessary to apply the RP methodology that allows optimizing the options for the location of the automated process control equipment according to the selected local criterion, given the cost limitation [4-10].

Robust design of means for automated control of the process of ECP of complex systems consists of determining the values of the parameters of the basic version of the construction of automated process control equipment for the ECP process, which provide the determination of the polarization potential in the selected range when the DF affects the ECP process. The ability to design means of automated control of the ECPTS process that are not sensitive to variations in the DF, while reducing costs, allows to control their technical level and quality.
The technical condition of the means for automated control of the process of ECPTS due to the influence of DF changes during operation. The effect of DF leads to a deviation of the functional characteristics from the target values [7, 9, 10].

There are two possible ways to minimize the impact of destabilizing factors on the technical characteristics of the modular structures of ECPTS facilities:

- elimination or limitation of DF sources;
- the elimination or limitation of the sensitivity of the means for automated monitoring of the process of ECP pipelines to the DF.

Practical possibilities for eliminating and limiting DF in the case of automated process control devices of the ECPTS process are expensive and complex. That is why when designing the means for automated control of the ECP process, the focus should be on eliminating and limiting sensitivity to DF and increasing robustness. Thus, the means for automated monitoring of the ECP process are called robust if their modular structures are insensitive to the effects of sources of variability, even if the sources themselves cannot be compensated.

For comparison of different variants of circuitry and design and technological execution of means of automated control of the process of ECPTS and finding the optimal variant in the design process, a quantitative determination of technical characteristics is required. The properties of the automated process control tools of the ECPTS process make it possible to determine whether the protection system is suitable for the customer. Correspondence to these properties determines the ability of the projected means of automated control of the ECPTS process to have characteristics close to the target at any time, under all operating conditions, throughout the life cycle.

Correspondence to properties means how much the characteristics of the projected means of automated control of the process of ECPTS can deviate from the target values in order to meet the requirements of a high technical level. The most important stage is the minimization of the full cost of design, including the cost of production, the cost of operation throughout the LC, the cost of technical losses.

The quality and cost of the automated process control equipment produced by ECPTS are determined to a large extent by the technical design of the means for automated control of the ECPTS process and the production process. The cycle of creation of means for automated control of the ECPTS process can be divided into three partially overlapping stages: design of means for automated control of the ECP process, design of the process and production.

In order to effectively ensure the quality of means for automated control of the ECPTC process, quality assurance methods are required at the design stage, which are aimed at improving quality rather than assessing it.

The process of means designing for automated control of the process of ECPTS, resistant to various types of DF, can be divided into two stages:

- conceptual design of means for automated control of the ECPTS process;
- parametric design of means of automated process control of ECPTS.

4. Conclusion
Means of automated control of the process of ECPTS belong to the class of complex systems, and there are many factors that can affect the value of the output characteristic in a complex way. It is detected that the design stage is the main stage for improving the quality of ECP automated control equipment. Methods for minimizing the effects of destabilizing factors on the technical characteristics of the modular structures of ECPTS are determined. Only systemic quality improvement at all stages of the life cycle of the means of automated ECPTS control allows achieving the required technical level indicators.

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