IMPROVEMENT OF TECHNOLOGIES FOR THE DEVELOPMENT OF MODERN RAIL AUTOMATION SYSTEMS

СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИЙ РАЗРАБОТКИ СОВРЕМЕННЫХ СИСТЕМ ЖЕЛЕЗНОДОРОЖНОЙ АВТОМАТИКИ

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Abstract: *Until Currently in the countries of Europe there is an intensification of the introduction of modern microprocessor systems of railway automation and the increase of their functional capabilities. The introduction of additional functions of control and monitoring systems, tightening of the requirements for the safety of their operation, mutual integration and unification of systems for various purposes, the complication of the implementation of processing of logical dependencies require fundamentally new approaches to the development of software and hardware of a new generation. In this regard, scientific and applied research aimed at the development of appropriate technologies is being conducted, based on the common methods and tools used in the formation of control and monitoring systems for various objects of the railway transport infrastructure. The proposed material contains the main results of such studies conducted over the past five years, as well as the main directions for further improving the development of microprocessor-based rail automation systems.*

***KEYWORDS**:* RAILWAY AUTOMATION, DEVELOPMENT, TECHNOLOGY, INTEGRATION, LOGICAL DEPENDENCIES, CONTROL SYSTEM, TRANSPORT INFRASTRUCTURE

1. Introduction

Currently, in Europe, there is an intensive development of rail automation systems involved in the management and regulation of train traffic, as well as the implementation of shunting work. Modern systems are built on a microprocessor-based element base with application of programmable logic. Several generations of such systems have already changed. Systems of the first generation, which appeared in the late 70's - early 80's of the last century, used symbiosis of the microelectronic and relay-contact element base, laying on the latter almost 100% of the responsible functions. Those. full responsibility for ensuring the conditions of traffic safety is assigned in such systems to relay-contact logic elements and finite state machines. The second generation of transport automation systems (90s of the last century), similar to the first generation, also represented a combination of a microprocessor and a relay-contact logic component. However, unlike the previous generation, there is a division of responsibility for the safety of the functioning of systems between relay and microprocessor components. The degree of distribution depends on a number of factors, among which: the functional purpose of the system, the type of technological control object, the type of microelectronic components used, the way of reserving information-control channels, etc. The third generation of rail automation systems (late 90s - early 2000s) is characterized by the fact that all the logic of functioning in them is programmable, while the switching of power circuits is performed by means of relay components connected to the windings and contacts of the modules O and input. In such circuits, the relays perform the function of exclusively contactors, without participation in the implementation of the dependency logic. In the systems of the fourth generation (2000s - present), all the logic of the functioning and implementation of the execution of commands are performed on programmable microprocessor components - without the use of relays. In such a system, the implementation of the dependency logic is performed by a separate subsystem, and the execution of commands by specialized object controllers [1 – 3].

The most interesting are the systems of the fifth generation, which began to develop actively after 2010. They are characterized by mutual integration and unification of systems for various purposes on the basis of a single core of management and control [4, 5].

For automation systems of different generations, fundamentally different approaches to the preparation of the turnkey management complex are applied, including design, production, safety proofing and commissioning. At the same time, it is the design and proof of security that, in the opinion of most experts in the field of knowledge, are the most important components of the technology for developing such responsible systems.

At the same time, for systems of the last two generations, which are the most economical and efficient from the point of view of performance indicators, many aspects of the above components are fundamentally unresolved. The task of the conducted research is to form preliminary bases for the subsequent solution of an important scientific and applied problem of improving technologies for the development of modern rail automation systems.

2. Preconditions and means for resolving the problem

2.1. Methodological and practical basis for the development of methods and design tools

Automated design of modern railway automation systems involves the following main areas: software design (configuration) and design of technical documentation. For these purposes, specialized application packages of CAD systems are used. The basis for the development of such systems used for transport infrastructure facilities is the principle of their territorial distribution.

In [5], experimental-static models of distributed process objects were proposed as a mathematical basis for improving methods and tools for computer-aided design. They are based on the graphic and analytical representation of the initial design object with the subsequent block decomposition of the graphic model. As a result, the implementation of the design scheme using this method looks like the diagram shown in Fig. 1.

The disadvantage of this approach is the excessive complexity for the user, primarily due to the inconvenience of the user interface and the need for specialized knowledge in the field of graph theory and matrix analysis.

At the same time, classical methods and means of computer-aided design are not in all cases acceptable for rail automation systems, taking into account their specificity. Thus, combining the method of forming a design object using experimental-static models and classical graphical shells (human-machine interfaces) is a method of solving this problem in the field of computer-aided design.

2.1. Methodological and practical basis for the development of methods and design tools

The main methods of proving the safety of railway automation systems are: methods of expert evaluation, calculated, experimental and calculation-experimental methods.

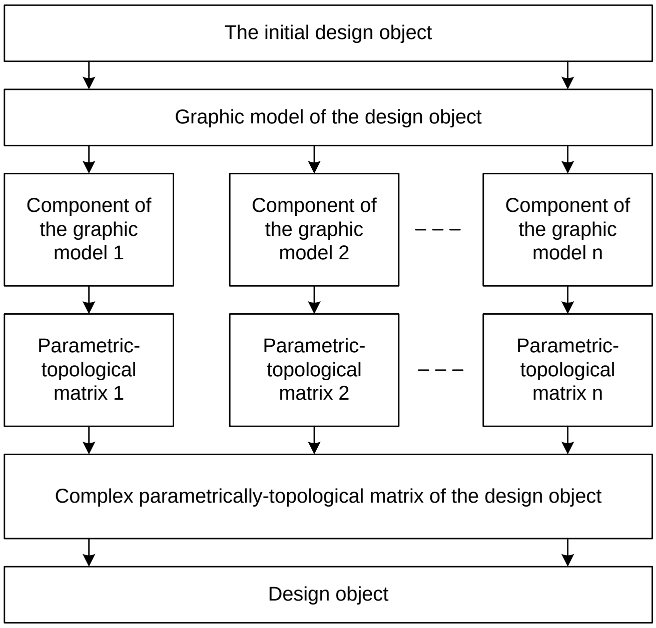

Fig.1. *Scheme of graphical-analytical design*

Of decisive importance are the experimental methods, which consist in the imitation, bench, combined and operational tests. Simulated and combined tests carried out in the laboratory conditions bear the main burden for revealing the features of the system's behavior, including failures, errors, etc.

It is these tests that can be automated as much as possible using specialized software test automation (robot testers) and test scripts that are put into these tools and implement the corresponding programs and techniques. An approximate simplified procedure for performing such tests is shown in Fig. 2.

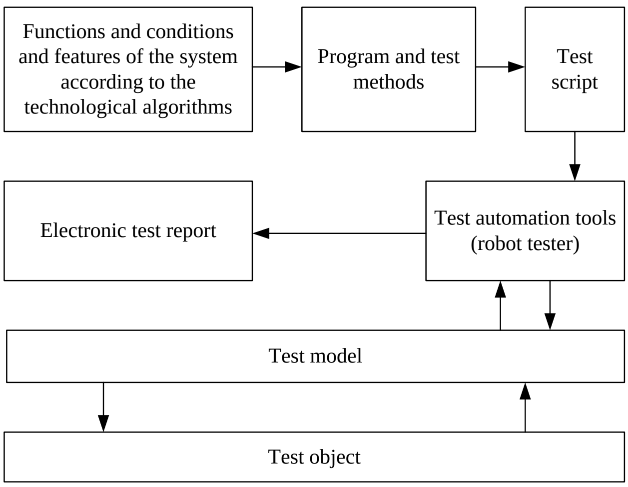

Fig. 2. *The existing simplified procedure for automating tests*

The main disadvantage of this approach is the complexity of providing and evaluating the test coverage of the functions, conditions and conditions of the control system. This is due to the fact that the program and test methodology, on the basis of which the test script is formed, is compiled by engineers on the basis of technological algorithms (technical specifications). At the same time, all possible combinations of states of the elements of the system, as well as "covered" (unintended) manifestations of the program and methodology may not be taken into account. Thus - an adjustment of the test automation method is required taking into account the objective evaluation of the test coverage and its provision.

Together, the solution of the two agreed problems in the direction of improving the technologies for the development of modern railroad automation systems of the fourth and fifth generations should increase the economic and technical efficiency of their creation. The evaluation of the corresponding effect depends on the purpose and specific modification of the control system.

3. Solution of the problem under consideration

3.1. Synthesis of the method and interface of computer-aided design

The solution of the problem of computer-aided design is the synthesis of the user's shell (user interface) with the means of forming the experimental-static model of the design object (the subsystem for processing logical dependencies, technical documentation, software, etc.). For this, a graphic editor with an external interface of an acceptable CAD package is created. This editor forms a modified graph of the experimental-static model, which together with the editor represents the custom shell of the advanced CAD system (Fig. 3).

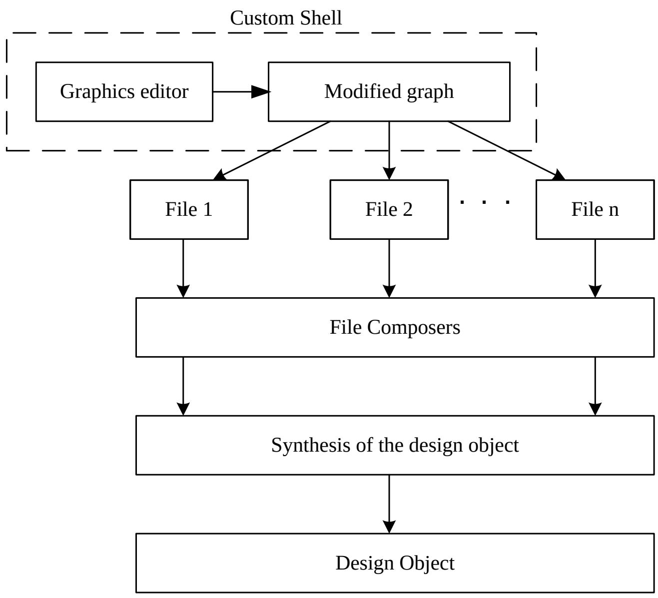

Fig. 3. *The scheme of computer-aided design taking into account the synthesis of the graphic shell and the experimental-static model*

In contrast to the classical experimental-static model proposed in [5], the proposed approach does not presuppose the preliminary formation of the components of graphs and blocks of parametrically-topological matrices in explicit form. Instead of them, files File 1 - File n, reproducing data blocks are generated directly on the basis of the modified graph. After composing these files, the synthesis of the design object is performed - similar to how it is done when using the classical experimental-static model.

The most important advantage of the proposed approach is the maximum adaptation to a user who does not have a special mathematical preparation, and the use of standardized human-machine interfaces.

The most promising environment for automated design, which is taken as the basis for the formation of the user's shell, is a CAD-type E-plan. The advantage of such an application package is maximum user adaptability, the ability to accelerate the design of large-scale objects, the use of convenient tabs and links, a sufficiently high speed. Taking as a basis the shell of this CAD will make it possible to create a universal means of automated design of railroad automation systems of any complexity.

Thus, the issue related to the effective use of graphic models and their analytic interpretations (in the form of matrices) in the problems of computer-aided design is solved.

3.2 Creation of self-learning system of automated tests

As it was noted earlier, the most important advantage of imitation and bench tests is the possibility of their maximum automation - with the exception or minimization of human participation in the trial process. At the same time, however, the human factor is not completely excluded under the existing approach (Figure 2) in connection with the design of the program and the test procedure followed by its interpretation into a test script by a test engineer (a group of engineers). In this regard, at least it is not guaranteed to provide 100% of the test coverage of the functions, conditions and properties of the control system.
The solution to this problem is the implementation of self-learning test scripts (Fig. 4).

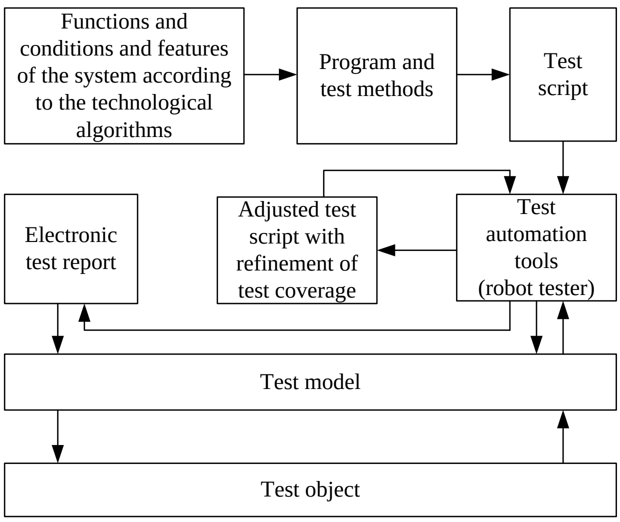

Fig. 4. *The procedure of automated tests with self-learning test script*

With this approach, the procedure for performing automated tests is generally similar to the original version (Fig. 3). However, in the scheme (Fig. 4) it is stipulated that only the basic (initial) test script is formed on the basis of the program and the test procedure by the test person. It is formed and used only before the first test cycle.
On subsequent cycles, the test automation tool generates a corrected test script, taking into account the actual coverage of the functions, conditions and properties of the control system. For this test script, feedback is provided to the test automation facilities, in accordance with which the technological information of this script is written to the memory devices of these means. Thus, a system is formed in which the automation tools independently form a test scenario using some initial data (the initial test script) and dynamic test coverage results.
In turn, the evaluation of the test coverage is formed on the basis of information obtained on the basis of the dynamic (test) analysis of the test object (control system) through the information channels of feedback. Only when determining the complete (100%) coverage of all functions, conditions and properties of the system is the feasibility of testing determined. This is done by a special algorithm (Fig. 5).
The initial data in this algorithm are the sets of input signals of the control system, on the basis of which, in turn, the sets of output signals and internal states are formed. On the basis of these sets, sets of combinations of functions, conditions and properties of the system are formed, which actually represents a test coverage without taking into account the reaction of the system to such combinations. After the initial test script is formed, the above combinations are cycled through according to their indexing. Only after this is done, the test coverage is checked (branch operator in Figure 5). Only after the positive test results is formed a dynamic test script. Otherwise, the cyclic operation is repeated until a complete test coating is provided.

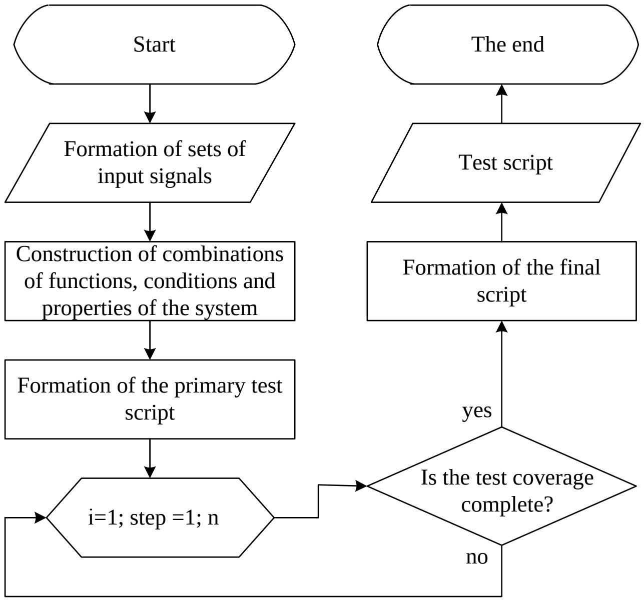

Fig. 5. *Algorithm for generating a dynamic test script, taking into account testing of the test coverage*

Performing the process shown in Fig. 5 of the cyclic procedure is realized during the direct execution of automated tests with subsequent testing of the test coating. Thus, the first few test cycles serve not to reveal the properties of the system (including failures and failures), but to provide self-learning test scripts. The number of these cycles depends, first of all, on the scale of the transport infrastructure object, which is subject to testing. For control systems for various purposes and for a particular application, this number of cycles can vary within fairly wide limits.
However, however, the methodology (procedure) for evaluating the test coverage, which is performed on the basis of combinatorial analysis, remains unclear. The algorithm for its implementation is shown in Fig. 6.

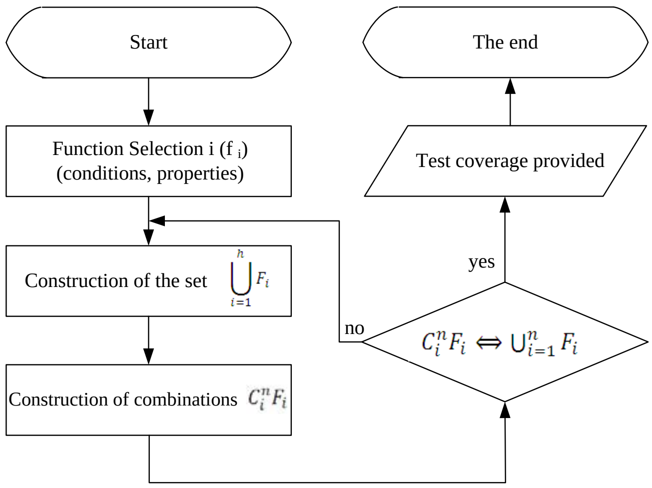

Fig. 6. *Algorithm of combinatorial evaluation of test coverage*

The algorithm works as follows. At the first stage, the union of the sets of all functions, conditions and properties of the system $\bigcup_{i=1}^{n} F_i$. After that all their possible combinations are determined $\tilde{N}_{i=1}^{n} F_i$. The completeness of the test coverage is determined on the basis of a one-to-one correspondence of the specified combination of sets and combinations of functions, conditions and properties of the system. In fact, the algorithm in Fig. 6, is an embedded algorithm for Fig. 5. Completely executed test coverage is a guarantee of

verification of all functions, conditions and properties of the system.
However, even as a result of the procedure in Fig. 6 the test coverage problem is not completely solved, which may be due to the identification of additional system properties in the testing process. These properties should also be taken into account in the assessment of the test coating. The corresponding algorithm is shown in Fig. 7.

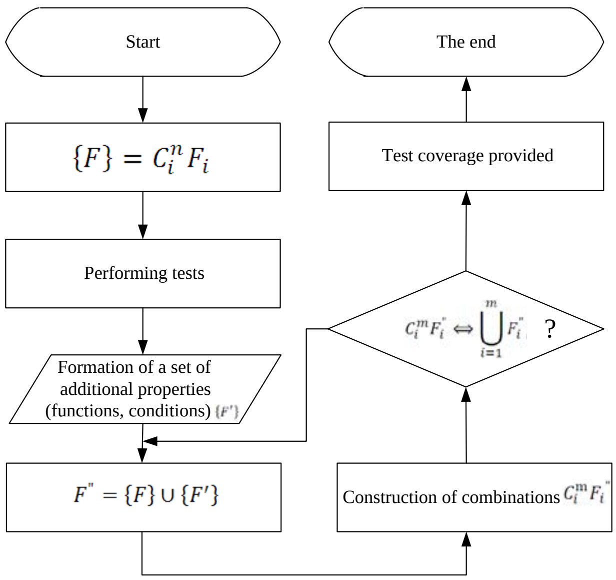

Fig. 7. *Algorithm of combinatorial evaluation of test coverage, taking into account the identification of new systems*

Initially, the initial set of combinations of functions, conditions and properties of the system *{F} =* $\tilde{N}^{n}_{i=1}F_i$. In the process of testing, an additional set is formed, identified during their conduct *{F'}*. As a result, a set of initial and additional (revealed in the test) properties of the control system is formed *F" = {F} + {F'}*. The subsequent operations with the resulting set are carried out in a manner analogous to the algorithm in Fig. 6.
Another important aspect of carrying out automated tests in conditions of self-learning test scripts is the correction of the original program and the test procedure taking into account changes in these scripts. The fact is that according to the current normative and technical documentation for testing, it is the program and methodology that is the guiding document, according to which the order and conditions of testing are regulated. This is especially true for the certification of control systems, in which the technical documentation for the system (including the program and test procedure) is an integral attribute of the object of certification. In such circumstances, the guidance document must necessarily be aligned as an updated test script, and in accordance with the current regulatory technical documentation. However, adjusting the program and test methodology only on the basis of the test script does not guarantee unambiguous compliance with regulatory requirements, since certain aspects and results of self-learning test scripts may not correspond to these requirements. At the same time, these discrepancies must be taken into account both in the guidance document and in the script itself. This should be taken into account in the final test cycle. The algorithm for performing the corresponding check and making corrections based on it is shown in Fig. 8.
As a result of the implementation of the above algorithm, if there are any inconsistencies in the test script, the corresponding normative and technical requirements are corrected.
The final results can only be the results of the latest spraying cycles, under which the program and methodology for their implementation have not changed.

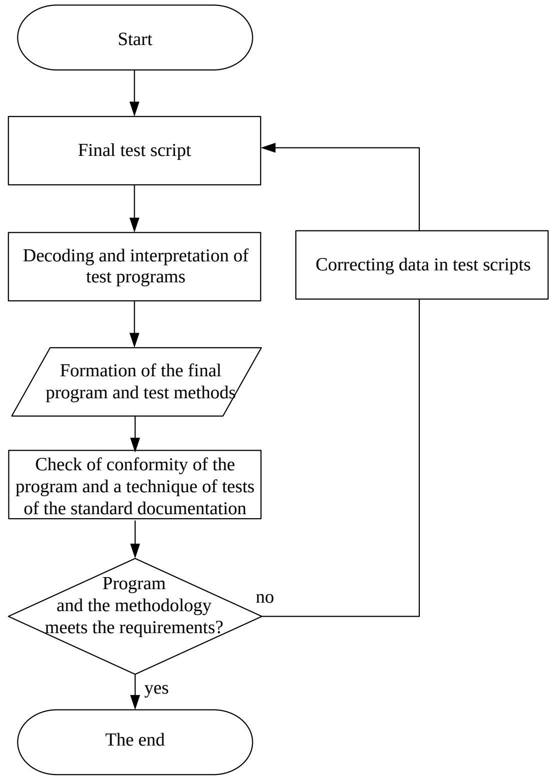

Fig. 8. *Algorithm for adjusting the program and test methodology, taking into account changes in the test script and regulatory requirements*

The resulting electronic test report must be consistent with the final versions of both the test program and methodology, and the test script.

4. Conclusion

Thus, in the technology of the development of modern systems of rail automation there are two main problems - the automation of design and automation of safety tests. Within the framework of solving the first problem, an approach based on the synthesis of the graph-analytic design method and the graphical user shell is proposed. To solve the second problem, an approach based on self-learning test scripts is proposed. Additionally, a set of procedures for verifying the correctness of the results of self-study is proposed. The results of the research are practically applied in the conditions of the development and implementation of a microprocessor system for the electric interlocking of pointers and signals at a number of railway stations.

5. Literature

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