Improvement of the scientific bases of creating means of automation of documentation of devices of railway automation and telemechanics

Abstract. The scientific principles of improvement of automation information for appliances of automation and telemechanics system consisting of integration of technology of conducting, use of the uniform standard format and reference information, succession of databases of technical documentation information is created. As a result, the possibility of optimal selection and functional completeness of software for monitoring operational and technological processes was created. The principles and methods of building electronic document management systems using the decomposition of the documentation process to a set of elements and their relationships are developed. The system of organization, control and use of technical documents in the field of automation and telemechanics, systematized through the characteristics of the created scenarios and technical documents of device control and their information, is considered.

1 Introduction

The leading positions in the world are occupied by the production of technical means and technologies ensuring the safety of high-speed trains, monitoring the continuity of rolling stock and increasing the efficiency of controlled transport and technological processes. In this regard, special attention is paid to the automation of the processes of creating a database of technological situations in each link of train control in real time, the automation of technical documentation processes, the implementation of which at each stage of maintaining electronic technical documentation will speed up the accounting of technical documentation in use systems of automated control and management in railway transport [1-6]. In the world, research is being carried out to improve the turnover system of scientific information of railway automation and telemechanics appliances, what is more to automate their reliability and control system. One of the important tasks in this direction, including the development of formal methods for the analysis, synthesis and research of electronic documentation, devices and modular automation tools for the process of detecting elements.

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2 The current state of creation of documentation automation tools and issues of increasing their efficiency
This technology is maintained and monitored using the instrument replacement metering journal. The study of this process showed that each year in the range of signaling and communication, there are a large number of cases of operation of expired devices at stations.

To ensure the quality of storage of technical documentation in signaling, centralization and blocking (SCB), it is vital to improve and execute automated methods for the procedure of computing and operation of railway automation and telemechanics appliance.

Automation of the ACR AT process, the formation of an information exchange system and the processing of technical documentation in electronic means should be carried out by developing specialized software packages using adaptation of existing information exchange tools that meet the requirements of signaling device control technology, holding into explanation the explicit of the directorial formation of automation and telemechanics, the standards of connection between the organization of railway transport.

3 Creation of principles and methods of control of automated technical documents

The electronic document of technical documentation (EDTD) model is presented. The formal model [12] of DT consists of three limited sets and interconnections of the elements of this set: 

U - a set of participants;
P - a set of processes;
F - a set of cases of technical documentation with a real range of values.

In this paper, we propose the concept of creating an automated electronic document management system based on the following concepts for the fast and tendency accomplishment of automated record operation in automation spheres for collecting industrial paper for signaling, centralization and blocking appliances:

1. Obtaining information on technical documents and their security.
3. The principle of adding, naming and version control.
4. The principle of collection, data use and storage point.
5. The principle of free text search.
6. The principle of automatic conversion.
7. The principle of integrated document management.
8. The principle of built-in regulatory compliance.

A structure is proposed for the exchange of information between databases of technical documentation created in various organizations (Fig. 1).

This is a database of technical documentation created in various organizations, at distances and in the management of signaling and communications, in other organizations that produce signaling devices, and, finally, it is an industrial database of technical documents for projects and technological processes. The conceptual model allows you to create a generalized formalized scheme (GFS) that describes all the objects of railway automation and telemechanics included in electronic document management [13, 14]. A generalized formalized scheme allows you to formalize all the processes of electronic documentation corresponding to different levels of the hierarchy.

GFS allows storage, synthesize and evaluate technical documentation and ensure data compatibility with software, automated record control and the quality of mechanization paper.

The matrix method of computerized record operation of technological document corresponds to the synthesized GFS, which provides and evaluates the effectiveness of electronic document management and the quality of technical documentation (TD) for various EDTD organization options.
4 Formalized methods of analysis, synthesis and study of automated record circulation of technical documents
A formalized scheme was developed, including a set of particular algorithms $A_g$, $g = 1, G$ of the ACRAT process. Algorithms $A_g$, $g = 1, G$ are synthesized based on an analysis of the state of existing modern electronic document management technologies.

Given the characteristics of the participants in the process, the ACRAT algorithms are given indices $A_{q,g}$ (Fig. 2).

A method of computerized record operation of technological document is compiled on the basis of data sets. For a set of states $F$, a graph vertex is selected; for a set of process $P$, graph edges are selected. The proportion in which the vertex of the diagram coincides to one detail of the position $F$ is selected; one element of point $P$ coincides with the edge of the chart; one vertex of the graph coincides to one unit of the position of rules $F$; one edge of the chart coincides to one unit of the set $P$.

Fig. 2. Algorithmic level of the process ACRAT
Imagine a graph of workflow of mechanization paper in the form $G = (V, E, \Gamma)$ where $V$ is the set of graph vertices, $E$ is the set of graph edges, and $G$ is the set of relationships.

The term graph theory method is applied to the process of processing technical documents. In this case, the workflow directions that occur correspond to the graphic directions. (Fig. 3).

There are five possible paths on the graph that are denoted by edges:

- $S_1 = P_1, P_4, P_5$
- $S_2 = P_2, P_10$
- $S_3 = P_1, P_3, P_10$
- $S_4 = P_1, P_3, P_6, P_7, P_8, P_9, P_10$
- $S_5 = P_1, P_2, P_6, P_7, P_8, P_9, P_10$

Fig. 3. Count transitions of the technological process of maintaining technical documentation of railway automation and telemechanics. The specified paths correspond to workflow scenarios.

Definition 1. The Ag algorithm is a set of operations performed during a sequence of particular performances and confirmation of logical positions in the method of ACR AT.
**Definition 2.**

where, an L of the form:

\[ A_{T} = \sum_{m=1}^{M} f_{m}(\alpha_{1}\alpha_{2}\alpha_{3})Z_{m} \]

Table 1. The truth table of \( A_{T} \) for three LC with the designation of the same parts of the LDA
We construct a transition table for this LDA (Table 2). The assignment of reproachful the LDA AT is to determine the minimal position of condition s with the tiniest quantity of L С, allowing obtain all output values.

Table 2. LDA conversion table AT

<table>
<thead>
<tr>
<th>α₁</th>
<th>α₂</th>
<th>α₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>01</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

So, from Table 2 we obtain the condition function \( f(\alpha_1\alpha_2\alpha_3) \) for LDA AT:

\[
f = \alpha_2\alpha_3 \lor \alpha_1\alpha_3 \lor \alpha_1\bar{\alpha}_3
\]

By performing the minimization, we obtain the following result:

\[
f = \alpha_2\alpha_3 \lor \alpha_3(\alpha_1 \lor \bar{\alpha}_1) = \alpha_2\alpha_3 \lor \alpha_3
\]

The proposed LDA AT minimization method allows one to obtain output values when finding the minimum set of terms with the smallest number of L Сs.

5 Mathematical description of the procedure of computing and operation of automation and telemechanics appliances

Based on the development of the created logic diagrams of the algorithms in the ACRAT system process, the block diagram of the automated method of technical documents is included, the micro-commands related to the logic diagram of the algorithms of technical documents are systematized and the tasks of the system machine are simplified. The stages of accounting for devices and their control are important in the field of railway automation and telemechanics.

A set of process states \( S \) is a set of all steps that have access to information by a document in the field of a simulated workflow. Using workflow notation, this definition is written as follows: \( \{S\} \equiv \{\} \)

EDTD to define the set \( F \), we use the corresponding elements of the set \( P \): \( \{F\} \equiv \{P\} \)

automaton and the set of participants: \( \{A\} = \{Y\} \)

\[
M = (A, S, Z, s_0, F, E)
\]
where $A$ is the input alphabet; $S$ is the internal alphabet; $Z$ is the output alphabet; $H$ is the transition function, which is determined by the transition table and defines the mapping of two sets $A \times S \rightarrow S$; $E$ is the function of the outputs, which is determined by the table of outputs and sets the display $A \times S \rightarrow Z$.

The structure diagram of a formalized model of technical documentation is developed using a micro-program machine (MM). The proposed structural diagram of a formalized model of technical documentation consists of a matrix of external micro-operations $M_1$, a matrix of internal micro-operations $M_2$, a matrix for generating the code for the following micro-command $M_3$.

Each external micro-operation state $Z_V q_g$ is an operator that controls, and the internal state $Z_\alpha q_g$ is a logical condition ($\alpha_qg = 1$; marked with a + sign) fulfilling or not fulfilling a condition ($\alpha_qg = 0$; marked with a - sign). Shows a defined scheme for determining process value in process structural states $Z_\alpha q_g$ under investigation (Fig. 4).

Process firmware, i.e. the stage of micro-operations in the process is described in a meaningful way in LDA language, and system external micro-operation $Z_V q_g$ is associated with the operator system $V_qg$, and state internal micro-operation $Z_\alpha q_g$ the process will be associated with a logical state $\alpha_qg$.

Fig. 4. A graphic diagram of the systematized model of the technical document process was created in the organization of multi-process operation, any micro-instruction includes only one micro-operation (state external or internal) and during each micro-clock contains only one operator or logical process condition. The number of internal system states of the MM is determined in relation to the values of the elements of the LDA. The size of the matrices $M_1$ and $M_2$ depends on the value of the operators in the LDA state and the conditions of the logical system. In a certain case, when the LDA consists only of operators, the matrix $E_3$ is obtained.
M2 does not exist. In this case, the number of consecutive micro-commands is always systematically generated in the M3 matrix.

If it is necessary to determine the matrix in the state M2, in this case they will be created $Z_{\alpha q g}$. With a false value of the checked in the $Z_{\alpha q g}$ conditions in the logical state (if it enters the LDA without inversion), the order of formation of the elements in the LDA state is violated.

Simplification of the MM state circuit can be obtained by simultaneous analysis of external and internal micro-operations. After that, the number of micro-commands of MM is determined not only by the values of LDA elements, but also by the number of groups of micro-operations created at that moment. In LDA A71, 6 such groups are systematically distinguished:

$$A71 = V_0 \downarrow V_{711} V_{712} V_{713} V_{714} \downarrow V_{715} V_{716} \downarrow V_{715} V_{716} \downarrow V_{718} \alpha_{711} \uparrow V_{7110} \downarrow V_{7111} \alpha_{712} \uparrow V_{7112} \downarrow V_{7113} \downarrow V_{7114} V_6$$

$$\times \downarrow V_{7115} \alpha_{713} \uparrow V_{7116} \alpha_{714} \uparrow V_{7117} \omega \uparrow V_{7118} \omega \uparrow V_{7119} \omega \uparrow V_{7120}$$

In the case of MM, there are six internal system-based states.

Each maximally corresponding group of LDA elements can be interpreted as a separate micro-command. Such a micro-command consists of a set of internal and external micro-operations, but simultaneously with a certain set of values of logical conditions, a micro-operation is performed that is included in only one branch of the micro-command.

Any internal process state software is associated with one compatible group of MiLDA elements. If the first element of the group Mj is the follower of one of the elements of the group Mi, then in M it is necessary to switch from the internal state to another. In this case, M performs the specified LDA.

To get the corresponding group $M_{Y_i}$ (that is, the group that is the first element), an LDA element $Y_i$ is written. If there is one follower (i.e. $Y_i$ an operator), then it is transferred to the right. If there are two followers, a branch will be organized, and each of them will be written to the right of a separate branch $Y_i$. This process is repeated for newly assigned group items in each branch.

If the group $M_{Y_i}$ includes the last LDA operator or if you want to enter an LDA element that does not correspond to at least one element of this branch, or if you need to record $Y_j$ the entry in another branch of the group $M_{Y_i}$, then the group $Y_l$ direction will be disabled. In the second case, you need to put the arrow $Y_j$ to $Y_l$. The formation of the group ends after the collapse of all its branches.

If the first group does not include all elements of the LDA, then the second group will be formed, starting with the smallest element in the LDA, not included in the previous group. Thus, the process is repeated until each LDA element is included in at least one group.

In the case of LDA, the process of systematic generation of A71 micro-commands is considered:

$$A71 = V_0 V_{711} V_{712} V_{713} V_{714} \downarrow V_{715} V_{716} V_{717} \downarrow V_{715} V_{716} \alpha_{711} \uparrow V_{7110} V_{7111}$$
\[ \downarrow^{716} \alpha_{712} \uparrow^{712} \downarrow^{711} V_{719} \omega \uparrow^{715} \downarrow^{714} V_{7115} \alpha_{713} \uparrow^{713} V_{7116} \alpha_{714} \uparrow^{714} V_{7117} \omega \uparrow^{716} \]

\[ \downarrow^{713} V_{7118} \omega \uparrow^{717} \downarrow^{712} V_{7112} V_{7113} V_{7114} V_k \]

**Definition 3.**

\[ M_{\alpha_{711}} = \{ V_0 \rightarrow [\alpha_{711}] \} \]

**Statement 1.**

\[ \alpha_{qg} = 1 \quad \Rightarrow \quad -\alpha_{qg} = 0 \]

\[ M_{\alpha_{711}} = \{ V_0 \rightarrow V_{711} \rightarrow V_{712} \rightarrow V_{713} \rightarrow V_{714} \rightarrow V_{715} \rightarrow V_{716} \rightarrow V_{717} \rightarrow V_{718} \rightarrow [\alpha_{711}] \} \]

\[ M_{\alpha_{712}} = \{ \alpha_{711} \rightarrow V_{7110} \rightarrow V_{7111} \rightarrow \alpha_{712} \rightarrow [\&^{-}[V_{719}] \rightarrow [\&^{-}[V_{712}] \rightarrow V_{7112} \rightarrow V_{7113} \rightarrow V_{7114} \rightarrow V_k \} \]

\[ M_{\alpha_{713}} = \{ V_{719} \rightarrow \omega^{715} \rightarrow V_{718} \rightarrow [\alpha_{711}] \} \]

\[ M_{\alpha_{714}} = \{ V_{7115} \rightarrow \alpha_{713} \rightarrow [V_{7118}] \} \]

\[ M_{\alpha_{715}} = \{ V_{7117} \rightarrow \omega^{716} \rightarrow \alpha_{712} \rightarrow [\&^{-}[V_{719}] \rightarrow [\&^{-}[V_{7112}] \rightarrow V_{7112} \rightarrow V_{7113} \rightarrow V_{7114} \rightarrow V_k \} \]

\[ M_{\alpha_{716}} = \{ V_{7118} \rightarrow \omega^{717} \rightarrow V_{715} \rightarrow V_{716} \rightarrow V_{717} \rightarrow V_{718} \rightarrow [\alpha_{711}] \} \]
Thus, the amount of these elements cannot serve as a sign of the complexity of the circuit. The complexity of the scheme is determined by another LDA, which is called extended and is designated as.

**Definition 4.** An advanced LDA is compiled according to the existing microcommand system, and the number of its elements is exactly equal to the value of the operators and logical conditions in the state microinstructions process.

If in the initial LDA there are no duplicate elements, then in the extended LDA the same elements can be repeated several times.

To obtain the microcommand system (12), the extended LDA will have the form:

\[
U_{\alpha 71} = V_{0}V_{712}V_{713}V_{714}V_{715}V_{716}V_{718} \uparrow V_{7110}V_{7111} \uparrow \alpha_{712} \uparrow V_{719}V_{718} \\
\omega \uparrow V_{7115} \uparrow \alpha_{713} \uparrow V_{7116} \alpha_{714} \uparrow V_{7117} \omega \uparrow \downarrow V_{7115} \omega \uparrow V_{714} \downarrow V_{13} (16)
\]

\[
V_{7118}V_{715}V_{716}V_{717}V_{718} \omega \uparrow V_{7112}V_{7113}V_{7114}V_{k}
\]

**Definition 5.** Depending on the specified compatibility conditions for the elements of the LDA and the selected method of forming microcommands from the same LDA, various systems of microcommands and, therefore, various extended LDAs can be obtained.

**Definition 6.** The MM circuit is built according to the microcommand system. Each MM scheme corresponds to its own LDA, the same LDA will correspond to a whole set of MM schemes.

Therefore, to assess the complexity of the MM scheme, usage is appropriate extended LDA.

We turn to the system of microcommands obtained (16), and make some changes, defining and repeating the common parts of some microcommands. As a result, we can get a system of microcommands:

\[
M_{V_{0}} = \{ V_{0} \rightarrow V_{711} \rightarrow V_{712} \rightarrow V_{713} \rightarrow V_{714} \rightarrow V_{715} \rightarrow V_{716} \rightarrow V_{717} \rightarrow V_{718} \}
\]

\[
M_{\alpha_{711}} = \{ \alpha_{711} \rightarrow \downarrow \alpha_{710} \rightarrow V_{711} \rightarrow \{ \alpha_{712} \} \}
\]

\[
M_{\alpha_{712}} = \{ \alpha_{712} \rightarrow \downarrow \alpha_{711} \rightarrow V_{7112} \rightarrow \{ \alpha_{714} \} \}
\]

\[
M_{V_{719}} = \{ V_{719} \rightarrow 1 \}
\]

\[
M_{\alpha_{713}} = \{ \uparrow \alpha_{713} \rightarrow \downarrow \alpha_{712} \rightarrow V_{7113} \rightarrow V_{7114} \rightarrow V_{k} \rightarrow [V_{7118}] \}
\]

\[
M_{\alpha_{714}} = \{ \alpha_{714} \rightarrow \{ \alpha_{712} \} \}
\]

\[
M_{V_{7118}} = \{ V_{7118} \rightarrow 3 \}
\]
Fig. 5. Structural diagram of MM LDA A71 (a) and the diagram of MM with identical parts of LDA A71 microcommands (b)
6 Construction and research of a system for automating the documentation of railway automation and telemechanics appliances

Technical documents in the system process are constantly checked, and the state of access to the electronic documentation system “Auto system of accounting and control of railway automation and telemechanics devices” (ASA-CRAT) is checked. This system complex will be distributed in repair and technological section (RTS) of the signaling and communication distance of JSC Uzbekistan railways using ASA-CRAT servers and a database.

A conceptual model of a computerized method for computing and operation of signaling devices is proposed. The model consists of three levels. At the first level, management and distance managers of Signaling and Communication have access to authorization, equipment search, a report on requests and user registrations.

In the first level, the managers of the W department and the WB distance have access to authorization, equipment search, report on requests and user registration.

At the second level, the RTS engineer has access to maintain a new section, new equipment, information on instrument repair, stock information, printing a QR code of the appliance and scanning it.

In the third stage of the system, the alarm system has the ability to identify the electrician, find the device, replace the device with a new one, provide data results and read the QR code.

It is proposed to use the QR-coding system in the organization of accounting for railway automatic and telemechanical devices, while tracking their movement and operational identification. The use of QR codes is aimed at improving the quality and efficiency of work on replacing and repairing automatic and telemechanical devices, optimizing and monitoring device maintenance, simplifying technology and accelerating the collection of information about installed devices, and identifying and detecting equipment for troubleshooting (Fig. 6).

Fig. 6. QR code generation module

It is recommended to use the proposed technology for tracking and accounting of automatic devices and telemechanics using a QR coding system data collection of replacement devices, verify the correctness of device replacement, automatically identify a device for posting information on the repair process and reception, and automatically enter data on new devices received in repair and technological areas.
7 Conclusion

The method of creation of the formalized scheme of electronic document circulation of technical documentation for procedure of explanation and operation of appliances of railway automation and telemechanics on the foundation of logical schemes of the algorithms providing formalization of procedures of transition to the automated technology is developed. The proposed method allows to obtain the output values of the algorithms using the minimum set of elements with the least number of logical conditions.

A diagram method of automated record operation of mechanical paper is constructed, which counts the division of document flows into a set of participants, process and States. As a result, it is possible to effectively establish acceptable scenarios for the movement of documents in the procedure of computerized record circulation of mechanical paper and describe the likely States of documents and identify possible participants.

The hierarchical scheme of the model providing carrying out operational researches of electronic technical document circulation is defined. In this scheme, built on the basis of an abstract finite automaton, the operators of the pattern of the first level are described as algorithms, and in the matrices of the last level are represented by operations in the alphabet. In this case, it is possible to consider the matrix external and internal micro-operations, and the matrix of forming the code of the next micro-command.

The method of simplification of algorithms with logical schemes allowing simultaneously carry out minimization and coding of the automatic machine taking into account the various requirements connected with document circulation of systems of automatics and telemechanics is developed. This method makes it possible to synthesize the automaton model structures by moving from simple calculated microinstructions to complex functions that encode different states of the automaton while solving micro-operations in the internal process.

Tools for automated monitoring and control of direction in the state of software processes in the registration and control system devices with different operating systems based on the technical data of the devices, as well as with the use of an automated QR-code module have been developed. These tools allow you to implement real production situations, which received 4 certificates of registration of computer programs.

Automated record operation in the form of ASA-CCR provides the most complete functional support and develops the electronic executive part of the system, taking into account the technical conditions for the content of documentation of automation and telemechanics appliances.

The process architecture of an automated system consists of three hierarchical state levels, containing 11 specialized windows: the program window, the login window and 9 working windows that allow you to manage and control the devices.

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