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Structural – functional model of maintenance and repair of the traction substations equipment

The needing to improve the quality of formation and control of rail transport performance, the increasing of the repair organization level and raising the level of scientific-technical progress, designed to establish a close relationship between the strategic objectives of the railway and short-term objectives of the production activity, requires the application of new approaches to developing the quality indicators of railway transport efficiency. The development of evaluation methods of economic activity efficiency of railway transport is based on the achievements of science and technology and introductions of new ways of production organization.

Railway transport is the foundation of a modern economy. It acts as the object of market relations, from effective activity of which depends the functioning and development of all industries, businesses, associations and complexes. Despite a significant contribution to the country's economy, rail transport is currently in a difficult situation: up to this time the problem of moral and physical depreciation of railway main assets has not lost its relevance. For example, in the area of power supply, which relates to the complex infrastructure of railway transport, a significant amount of traction substations are working with a service life of over 40 years; most of the power and traction transformers are working with a service life of over 25 years [1, 2]. Key features of the traction substations equipment significantly lag behind foreign analogues. The slowdown in technological development of railway transport fixed assets decreases the reliability of railway infrastructure, but the inconsistency of the service quality parameters to the level of world standards reduces the competitiveness of railway transport on the transport area. The efficiency and quality of transport services for customers, and, accordingly, competitiveness is largely determined by the quality of technological processes and reliability of technical means.

In the world practice of solving problems related to quality of products and services it is usually achieved through the introduction the quality management system [3–5]. Development of business processes model, their optimization with using technologies of process engineering and systems management needs for the transition to a management system based on process approach [6, 7]. The aim of this work is to develop a structural – functional model of maintenance and repair process of the traction substations equipment for improving the quality of the process.

The results of the research work

Practical implementation of process approach on the enterprises involves the description of processes with all components necessary for its proper functioning. The expanded description of the process it is advisable to specify the following characteristics [8, 9]:

- the full name of the process (it should be brief and as clear as possible);
- process definition (the wording of which reveal the essence, the main content of the process);
- the purpose of the process (the necessary or desirable outcome of the process);
- process owner (the person responsible for forward planning, resource provision, and process efficiency);
- head process (the person responsible for ongoing planning and management of processes to achieve planned results);
- the standards process (with appropriate performance standards in accordance with the process);
- the inputs of the process (material and information flows in the process from the outside and to be converted);
- outputs of the process (the conversion results, adding value). Any process must have at least one output;
- resources (financial, technological, material and informational, through which the transformation of inputs into outputs);
- processes suppliers (internal or external suppliers – the sources of inputs of the considered process);
- processes of consumers (processes of internal or external origin, which are users of the results of the process);
- measuring parameters of the process;
- indicators of effectiveness and efficiency of the process (matching of the actual results of the process are planned, as well as the relationship between the result achieved and resources used) [10].

The most important characteristics of the repair process of electrical equipment etc., corresponding to the mentioned requirements is given in table 1.

On the basis of this table we can draw the following conclusions that characterize the equipment repair process:

- repair process is focused on power supply department and railways. Power supply departments are the recipients of products – working equipment, and railway in result – no interruption in the movement of trains;
- implementation of technological operations in the process must be strictly regulated. So it is regulated by several normative documents, which is covered in the standards process;
- repair process of equipment should always be configured on the expectations of consumers, which needs to know. Therefore, it is necessary to know the specific calculated indicators of efficiency of electrical equipment repair process;
- repair process is formed by a set of interrelated and work completed. The results of one operation is the beginning of another, forming a chain of internal suppliers and consumers. In other words, each participant in this process is both a consumer of the results of the previous supplier;
- each of the works in the repair process is usually performed by individuals or units of the distance power repair service. A separate unit or an employee of a repair service may participate in several papotech. It should be considered in repair planning.

Table 1. Characteristics of the repair process

The full name of the process	Maintenance and repair of substation equipment
Process definition	Meeting the needs of power supply department in the carrying out of works on maintenance of electrical equipment
The purpose of the process	Equipment maintaining in working condition with minimum labor and material costs
Process owner	Guide distance power
The manager of the process	Head of power supply department
The standards process	Standard documents, repairs history
The inputs of the process	• range of equipment; • equipment: – serviceable (requires planned repair); – faulty (broken in the accident)
The outputs of the process	• equipment that has passed maintenance; • repairs equipment (planned and unplanned); • report on the carrying out of works of maintenance and repair
Resources	• the maintenance services staff; • infrastructure (equipment, buildings, and industrial premises, transport, communications and so on); • material and time resources, required to perform all types of repair works; • software involved in the process
Supplier process	Power supply department and the railway
The consumer process	Power supply department and the railway
The measured process parameters	The cost of maintenance and repair, railway operations property damage as a result of power supply department equipment failures (trains delayed)
Performance and process efficiency	Generalized diagnostic indicator (quality management instrument)

Given the characteristics of the repair process of the traction substations equipment (table 1) to solve the problem of improving the quality of control and repair process of substation equipment the structural and functional analysis of this process for the power supply department has been performed. As a linguistic support for this task the International Standards Package Modeling IDEF (*Icam Definition*) has been used. It allows to analyze the process from three key perspectives at the same time – IDEF0 (*Integrated Definition for Function Modeling*), IDEF3 and DFD (*Data Flow Diagram*) [11–14].

IDEF0 – technology of structural analysis and design [15]. It is a modeling language, proposed over 25 years ago by D. Ross (SoftTech, Inc.) and named in the first edition of the SADT (Structured Analysis and Design Technique). According to this modeling language the analyzing process is represented in the set of a plurality of interrelated actions (*Activities*) that interact with each other based on certain rules (*Control*), taking into account consumption information, human resources and production (*Mechanism*) having a clearly defined input (*Input*) and at least a clearly defined output (*Output*).

IDEF3 – data collection technology, necessary for conducting structural analysis the system complementary to the IDEF0 technology. With the help of this technology it's possible to specify the painting process, drawing the analyst's attention to the sequence of functions execution, sub-processes and processes. The logic of this technology allows to build and analyze alternative scenarios of development processes („What – if"?).

DFD (*Data Flow Diagram*) – structural analysis of data streams. DFD diagrams allow us to describe the process of information exchange between elements of the system under consideration. DFD shows the data sources and destinations, identificeret processes and groups of data streams linking one function with another, and also, importantly, defines the drives (storage) of data that are used in the studied process.

IDEF modeling is a way to reduce the amount of costly errors by structuring the process in the early stages of creating intelligent systems that improve communication between users and developers and smooth the transition from analysis to design.

Based on the provisions of IDEF modeling is a complex task of repair process has been divided into a number of subproblems, the solution of which made it easier for deal with the original problem. Structural - functional modeling with the selection of events has been done according to the IDEF0 methodology; description of processes has been done according to the methodology IDEF3, and to build data flow diagrams DFD method has been used.

A general idea of the repair process of electrical equipment is presented on figure 1 in the form of diagrams A0. According to the IDEF0 methodology, the left side of units are designed for inputs, right for outputs, lower for mechanisms, upper for management factors. This designation outlines the basic system principles: input products are transformed into the source, system controlling restricts or specifies the conditions for performing the transformation, the mechanisms show who, what and how performs the functions of processes and sub-processes [16, 17].

Structural-functional model of repair process of electrical equipment, developed using the IDEF methodology, presented in figure 2. It is a detailed representation of the repair process and includes the most important sub-processes with their interrelationships, and the cells A1 to A4 of the lower level represent

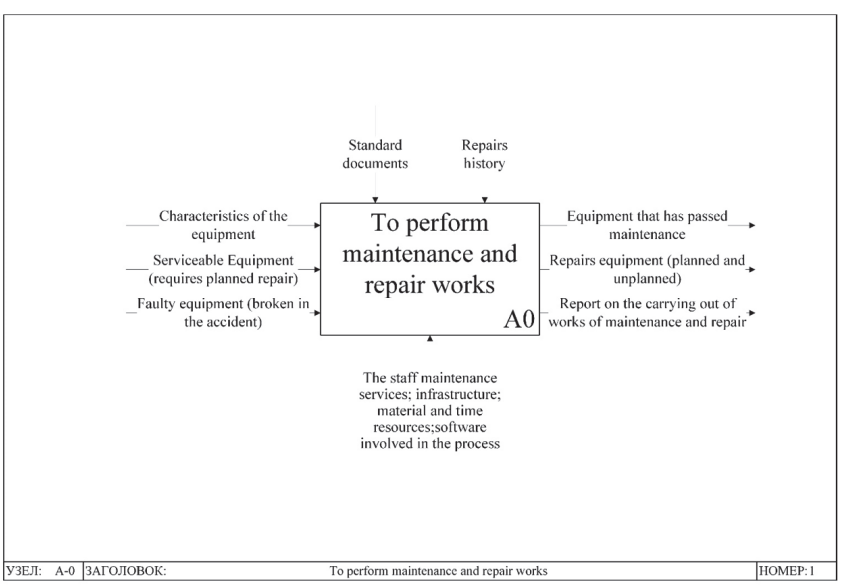

Figure 1. *Repair process of tracrion substation electrical equipment*

the detailed repair processes with the required level of detail.

The structural-functional analysis shows how the repair system functioned, and the relationship between electrical equipment repair processes. The list of nodes of the structural-functional model and the types of work corresponding to the stages of the process of electrical equipment technical maintenance and repair are presented in table 2. A list of nodes and the types of work corresponding to the stages of each subprocess of the structural-functional model presented in table 3.

Analysis of the structural-functional model nodes of the electrical equipment repair process shows that the largest number of subprocesses and, accordingly, the scope of work includes the node „Unscheduled repairs of electrical equipment" (fig. 3).

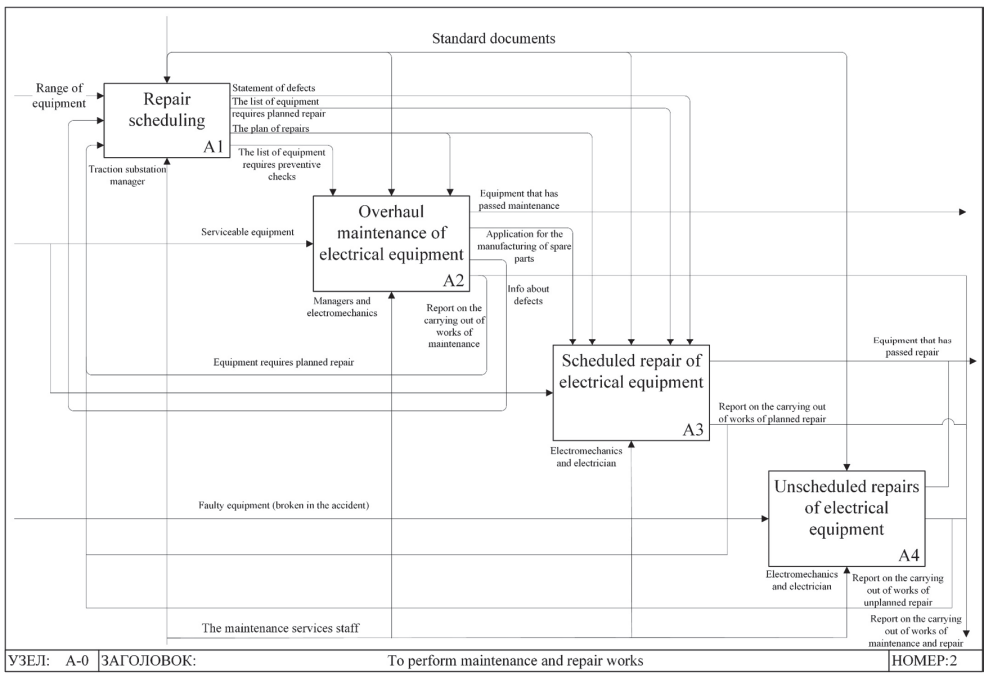

Figure 2. *Structural-functional model of maintenance and repair process of traction substation electrical equipment*

Emergency repairs caused by equipmenaccident or t not covered by the schedule of preventive maintenance (the node A4), inevitably leads to the addition of the previously formed production task of urgent, unscheduled works. This requires the expeditious identification of material and the complexity of the upcoming repairs (unit 4.5), and depending on the results of the evaluation to make a decision on purchase of necessary materials and parts (unit 4.4), requires replacing or making their by repair services forces (unit 4.6). In this case, the heads of maintenance departments again reviewed the timing and sequence of unscheduled repairs and scheduled earlier work and promptly assigned their performers (unit 4.6). An important node of this subprocess is the node A4.3 („The internal investigation and punishment of those responsible"). It requires additional human and time resources that carries unintended costs.

It should also be noted that at power supply department, which was completed structurally-functional analysis, there is no comprehensive evaluation of the effectiveness and efficiency of the maintenance services.

Conclusions

In this article compiled a detailed description and identified the main characteristics of the repair process of technological equipment necessary for successful functioning in the framework of network processes of the Electrification Department. Taking this into account, structural and functional analysis electrical equipment repair process has been performed and structural-functional model has been developed. The subprocesses of electrical equipment repair, governing documents, directors, contractors and reporting have been described in detail. The connection between this subprocesses and shared resources that are used by the performers of these subprocesses has been founded. It should be considered when planning the schedule outage. The greatest attention should be paid to the subprocess of unplanned emergency repairs of electrical equipment, as it requires additional financial and material costs.

This structural-functional model of electrical equipment repair process allows to plan resources for maintenance and repair on the basis of a detailed analysis of its components. The analysis of electrical equipment repair process with the using of this model can be used to develop the methodologies of reducing the time and material costs for maintenance and all types of repairs, as well as in the formation of regulations for the organization of electrical equipment maintenance and repair system of railways.

Table 2. The nodes of the structural-functional model of electrical equipment repair process

Node	The name of the electrical equipment repair subprocess
A1	Repair scheduling
A2	Overhaul maintenance of electrical equipment
A3	Scheduled maintenance of electrical equipment
A4	Unscheduled repairs of electrical equipment

Table 3. The nodes of the sub-processes of structural-functional model of the electrical equipment repair process

Node	The name of the electrical equipment repair subprocess
A1.1	Statistical analysis of the results of electrical equipment diagnostic tests
A1.2	The adjustment of the repair schedule
A1.3	Planning and allocation of resources for repair and maintenance work
A2.1	The organization of electrical equipment maintenance
A2.2	Execution the diagnostic tests of electrical equipment
A3.1	Execution the electrical equipment maintenance
A3.2	The overhaul of electrical equipment
A4.1	Identification of electrical failure causes
A4.2	Definition of works scope, performers, funding sources
A4.3	The internal investigation and punishment of those responsible
A4.4	The procurement of spare parts and materials
A4.5	The definition of material and time resources
A4.6	The formation of the job repair unit structure
A4.7	Execution the emergency repair of electrical equipment

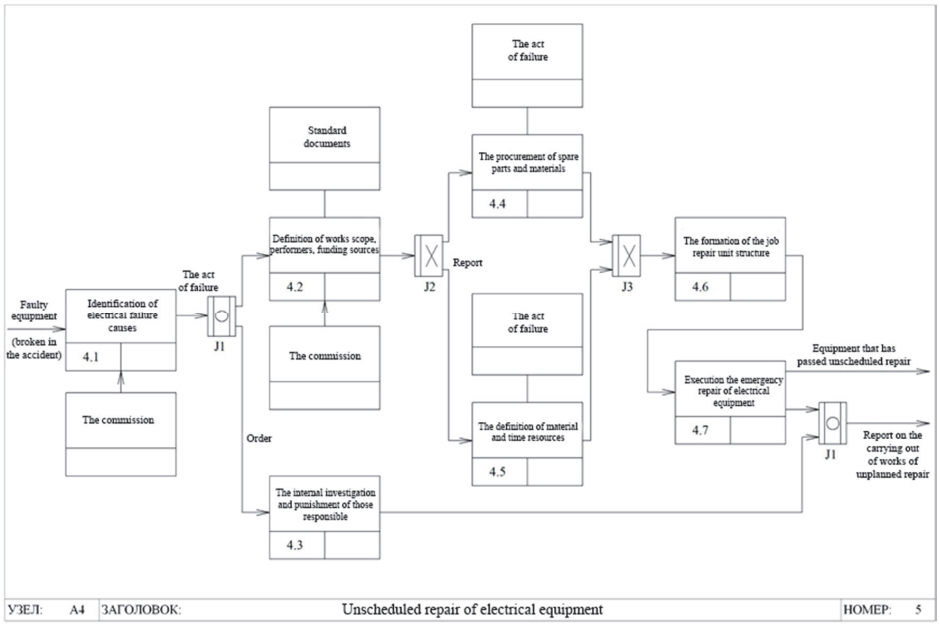

Figure 3. *Structural-functional model of the subprocess „Unscheduled repairs of electrical equipment"*

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Abstract

To solve the problem of improving the quality control of substation equipment maintenance and repair process the structural and functional analysis for the distances of power supply has been performed. As a linguistic support for this task the International Standards Package Modeling IDEF (Icam Definition) has been used. It allows to analyze the process from three key perspectives at the same time – IDEF0 (Integrated Definition for Function Modeling), IDEF3 and DFD (Data Flow Diagram). IDEF modeling is a way to reduce the amount of costly errors by structuring the process in the early stages of creating intelligent systems. It improves the communication between users and developers and smooth the transition from analysis to design. A complex task of equipment maintenance and repair process has been divided into a series of simple tasks on the basis of IDEF modeling. Structural - functional modeling with the selection of events has been done according to the IDEF0 methodology. Description of processes has been done according to the methodology IDEF3. DFD method has been used for building the data flow diagrams. Conducted structural-functional analysis has been shown that at some stages this process often requires the operational definition of different types of resources needed to perform repair work.

Key words: *electricity, traction substation, maintenance, diagnostics, structural-functional model, IDEF.*