INTERACTIVE APPROACHES TO THE ORGANIZATION OF STAFF INTERACTION WITH AUTOMATED CONTROL SYSTEMS

ИНТЕРАКТИВНЫЕ ПОДХОДЫ К ОРГАНИЗАЦИИ ВЗАИМОДЕЙСТВИЯ ПЕРСОНАЛА С АВТОМАТИЗИРОВАННЫМИ СИСТЕМАМИ УПРАВЛЕНИЯ

Prof. Sc.D. Moiseenko V.[1], Assos. prof. Ph.D. Kameniev O.[2], grad. Gaievskyi V.[3],
Department of specialized computer systems [1,3], Department of automatic and computer remote control of train traffic [2] – Ukrainian State University of Railway Transport, Ukraine

Abstract: *Until now, the majority of ergatic control systems in various technological areas are based on a functioning independent of the maintenance process. This approach reduces the efficiency of maintenance and the safety of the system. The report proposes an alternative model of the system's behavior, based on interactive interaction with both operational and technical staff.*

***KEYWORDS**:* CONTROL SYSTEM, INTERACTIVE INTERACTION, MAINTENANCE, OPERATIONAL PERSONNEL, TECHNICAL PERSONNEL

1. Introduction

Most automated process control systems are ergative systems. This means that there is a distribution of powers between the operator and the technical means [1].
At present, many approaches have been worked out to investigate and form an interactive interaction between the operator and the equipment. Thus, the principle of ergatics is provided, within the framework of which a comprehensive evaluation of the reliability, efficiency and safety of the functioning of the automated system is performed [2, 3].
However, little attention is paid to the interaction of technical means of the system with the servicing (technical) personnel, as well as the complex interaction of equipment, operational (operational) and technical personnel. In such conditions, the functioning of ergatic control systems becomes insufficiently explored, and approaches to rationing performance indicators do not take into account a variety of operational and technical factors. Particularly relevant is the problem for railway transport, information control systems which directly affect the safety of technological processes (train and shunting work).
Thus, a further study is aimed at taking into account the interactive interaction between all types of personnel and the technology of information control systems. This will allow to develop more reliable approaches to designing ergatic systems in industry, energy and transport.

2. Preconditions and means for resolving the problem

The technical staff of the automated control systems is currently ensuring the proper state of the performance indicators through the maintenance subsystem (Fig. 1). It includes a set of maintenance and repair works, regulatory documents and an organizational component [4].

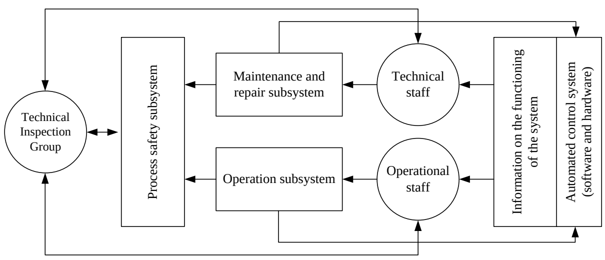

Fig.1. The existing scheme for ensuring the safety of automated control systems

The safety management scheme includes a set of maintenance and repair works, regulatory documents and an organizational component.

Technical personnel, guided by regulatory documents and visual information on the status of devices, carries out the necessary list of works. According to statistics, quite a significant number of security breaches in the implementation of technological processes occur due to errors of technical personnel: poor quality of work, violation of the deadline for their execution, use of non-normative materials and equipment, etc. In fact, the person and the control system in this situation operate in parallel and interact little . The system does not directly control the maintenance process, so this function has to be assigned to a separate headquarters, which checks the quality of maintenance and the operational safety. A similar situation is observed with the process of technical use of the management system, that is, with exploitation. Despite some progress in the algorithm of human-operator interaction, which can take place in modern microprocessor systems, the situation has not fundamentally changed. In fact, there are some developments in the interactive interaction of the system with the operator (the formation of warning dialog boxes with audible alarm in the event of damage, user authorization, confirmation of information, automatic provision of reference data on the analysis of the process at the facility, etc.).
Therefore, the operation of the operational staff is also controlled by individual staff, as shown in the diagram (Fig. 1). Over the past two decades, there has been a trend to strengthen this control system, but there have been no significant changes in the quality and safety of the maintenance and operation subsystems.
Consequently, there is a classic problem in the management system, which is called the watchman for the watchman. With this approach, the use of subjective control can have only one-off, short-term consequences and always reduces the effectiveness of the process. In this regard, it is proposed to change the system of interaction of the human operator with automated control systems. Unlike the existing method, the system will have built-in functions for operative monitoring of the safety of personnel actions, monitoring of operation and maintenance. In case of dangerous situations, the system will block the development of dangerous events by using intelligent subsystems: personnel diagnosis, identification and hazard localization (Fig. 2).

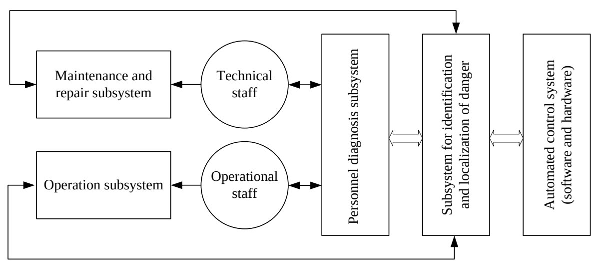

Fig.2. The scheme of safety on the basis of diagnosing the personnel

The subsystem of personnel diagnostics on the basis of programmed criteria determines the adequacy of the behavior of both operational and technical personnel in the current situation at the technological facility. If there are actions that do not correspond to the situation (for example, attempts to interfere with the operation of executive devices when performing their assigned functions), the subsystem issues a warning, and in case of its failure, by blocking the corresponding dangerous action with the help of the identification and danger localization subsystem. The control team enters the automated control system, including its hardware and software, only under condition of passage of the diagnostic control in both intellectual subsystems. The implementation of this approach can occur as software, or hardware or combined (software and hardware) tools.

3. Solution of the problem under consideration

3.1. Generalized formalization of interactive interaction

To implement the interactive scheme of interaction between personnel and technology (Fig. 2), an approach based on the formal-multiple establishment of the adequacy of the actions of personnel according to certain criteria is foreseen. It is based on the isomorphism of sets of states and actions, the definition of which is carried out using the apparatus of the theory of groups and relations. Each component of the scheme depicted in Fig. 2 is interpreted by an ordered set of objects, their states and properties. In the framework of a set, equivalence classes are formed according to a structural-functional feature. For each class, compliance is established at the level of the technical diagnostic subsystem, which is proved using the theorems on permutations of group elements [5].

At the same time, the criterion of inadequate actions of any personnel (operational or technical) is the violation of the established isomorphism detected by the diagnostic subsystem.

A separate stage establishes the adequacy of the complex interaction of all components associated with interactive interaction with the management system. For this, a pairwise comparison is performed with subsequent complex analysis using the graph-analytic method (Fig. 3) [6].

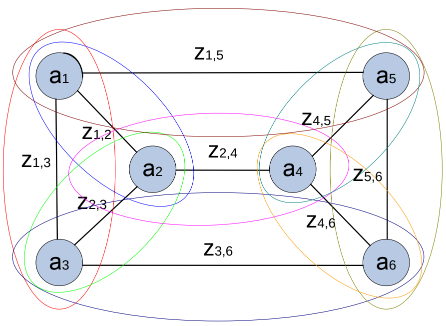

Fig. 3. Scheme of the complex definition of the adequacy of the interactive interaction of the ergatic control system

The correspondence of the vertices of the graph shown in Fig. 3, with the elements of the circuit in Fig. 2 is defined as follows: a1 – Maintenance and repair subsystem; a2 – Operation subsystem; a3 – Technical staff; a4 – Operational staff; a5 – Subsystem for identification and localization of danger; a6 – Software and hardware. The resulting correctness is determined on the basis of comparison of the actual ordered set of links $Z = \{z_{ij}\}$ with the reference one, which is laid in the subsystem of technical diagnostics.

3.2. Periodic monitoring of technical diagnosis

At the same time, there arises a single problem of controlling the reliability of the shadow diagnostics of an automated control system. At the same time, it should be borne in mind that the management systems for responsible technological processes are built on a multi-channel principle, which increases their safety. In such conditions, additional control of technical diagnostics can be carried out on the basis of information comparison in various control channels of controllers of executive devices (objects). An algorithm for such a control is shown in Fig. 4.

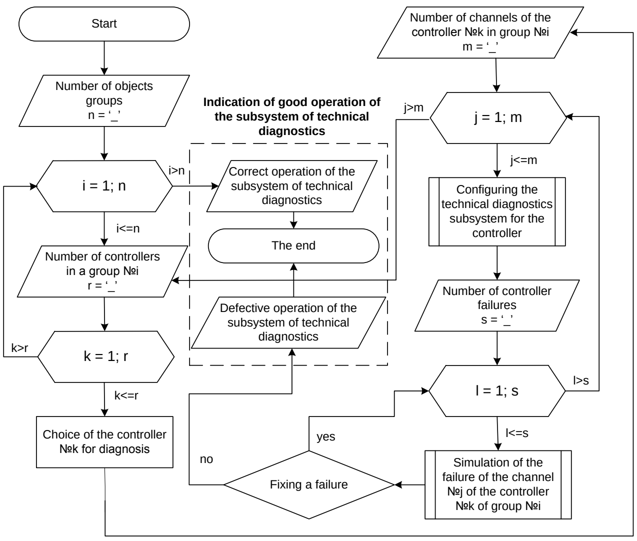

Fig. 4. Algorithm of periodic monitoring of the subsystem of technical diagnostics

The joint execution of the procedures depicted in Figures 3 and 4 gives the most complete picture of the functioning of the control system. Depending on the specific control system, these structures can be refined or detailed.

3.3. Intermodular interaction of functional components

However, the claimed procedure of the analysis requires clarification of the interaction between the functional components of the automated control system. Given the multi-level hierarchical construction of most such systems, as well as the client-server architecture of their construction, such interaction is displayed by the circuit depicted in Fig. 5 [7].

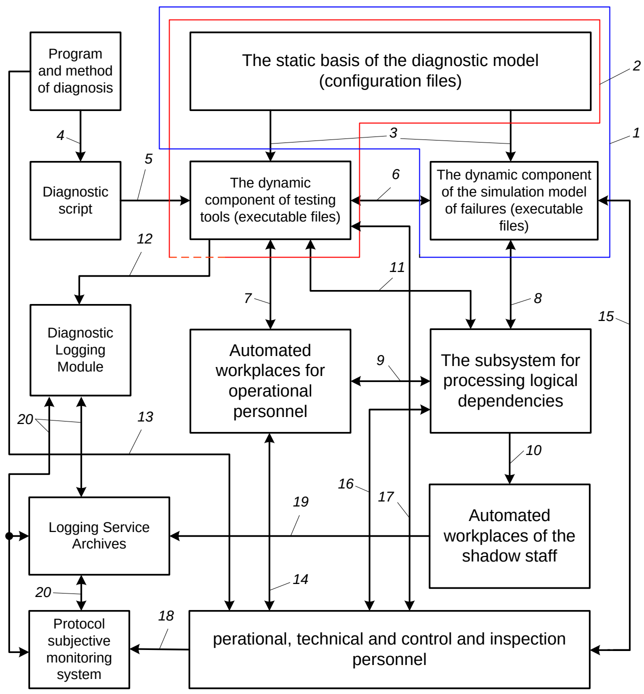

Fig. 5. Structure of intermodular interaction of components of the ergatic control system

The links and the elements indicated in Fig. 5, have the following meanings: 1 – Simulation model of sensors and actuators of the system; 2 – Software tool for automation of technical diagnostics; 3 – Process of synthesis (integration) of the simulation model and the means of automation of technical diagnostics; 4 – Process of forming a test script for technical diagnostics; 5 – The process of integrating the test script with the technical diagnostics automation tool; 6 – Process of initialization of states of sensors and actuators; 7 – Actions of operational personnel or their modeling (reproduction); 8, 9, 10, 11 – Monitoring the response of the subsystem for processing logical dependencies on test and diagnostic impacts, respectively, from the simulation model of sensors and actuators, automated workstations of operational and technical personnel, automation tools for technical diagnostics; 12 – Automatic registration of diagnostic results in an electronic protocol; 13 – Process of interaction of the control and inspection personnel with the program and the diagnostic technique in the non-automatic mode; 14 – Process of interactive interaction of operational personnel and the system or its modeling (reproduction); 15 – Process of changing the states of sensors and actuators of the system; 16 – Process of modeling the actions of destabilizing factors; 17 – Setting up an automated diagnostic tool; 18 – Manual (non-automatic) registration of the results of technical diagnostics by inspection personnel; 19 – Analysis of the results of the logging of the system during the technical diagnosis; 20 – Comparison of manual and electronic reporting on the results of technical diagnosis.

The initial component of the process of objective control of the interactive interaction of personnel and equipment is the simulation model of sensors and actuators 1, which is synthesized 3 on the basis of combining configuration and executable files. software system diagnostics automation is formed for the automation of technical diagnostics 2 synthesized similarly to the simulation model.

The initial position of the technical diagnostics is the program and methodology, on the basis of which 4 test (diagnostic) script is formed, which is laid 5 in the diagnostic automation tool. According to it, the automation tool establishes the initial, current and final states of the sensors and actuators (including simulating their failures and failures) 6 and reproduces the operator's work by simulating manipulations at the workstation's automated workplace under the respective conditions of the sensors and actuators 7.

The installed states of the sensors and actuators and the operator's commands are fed into the subsystem for processing logical dependencies, the reaction of which to them is perceived and controlled by the means of the simulation model, the automated workstations of the operative, technical personnel and the diagnostics automation media through channels 8, 9, 10, 11 . also, the channel means 11 sets the automation of technical diagnostics various states of logical dependencies processing subsystem channels (including ITPO destabilization in their work) and internal controls of their reaction to the impact of external factors. Fixed reaction 12 is automatically registered in the electronic record. In addition, the information is archived by the service logging of the control system, which can be read by means of automated workplaces of technical personnel (to which it comes via channel 10) or directly (decryption of protocols). Comparison of the system operation protocols with the electronic reports of the diagnostic automation tool 20 makes it possible to verify the correct functioning of the logging service as an integral part of the security of the control system.

If there is no automation of technical diagnostics or a combined approach in which only part of the technical diagnostics procedures are automated, the representative of the inspection personnel directly follows the provisions of the program and the technique of technical diagnostics, 13 simulating the work of the operator 14 in accordance with them, changing the states of the sensors and actuators 15 and destabilizing a work logical dependencies processing subsystem 16. With the help of the operator 14, the service persons interfaces Ala 10, adjustment and testing 15, 16 the reaction of various components of the complex's control system is analyzed, which is recorded in the protocol of technical diagnostics.

In the case of partial automation of the technical diagnostics process, the automation tool can be used to perform individual phases of the program and the diagnostic procedure, for which it is preconfigured before the diagnostic procedures begin, and start and stop 17 during interactive interaction. With the full automation of technical diagnostics, even if the adequacy of diagnostic imitation models has been confirmed, the expediency of additional verification of their results by control tests has been established.

At the end of each cycle of technical diagnostics, a comparative analysis of 20 electronic, manual protocols and archives of the logging subsystem of the logical dependency processing subsystem or only the manual protocol and logging archives (provided there is no automation), on the basis of which a report on the performance of technical diagnostics is prepared and processed Results using standard methods of the theory of experimental planning.

Thus, corresponding to the scheme shown in Fig. 5, the automated control system should simulate two interface lines of interaction with sensors and actuators – virtual and real (Fig. 6) [8].

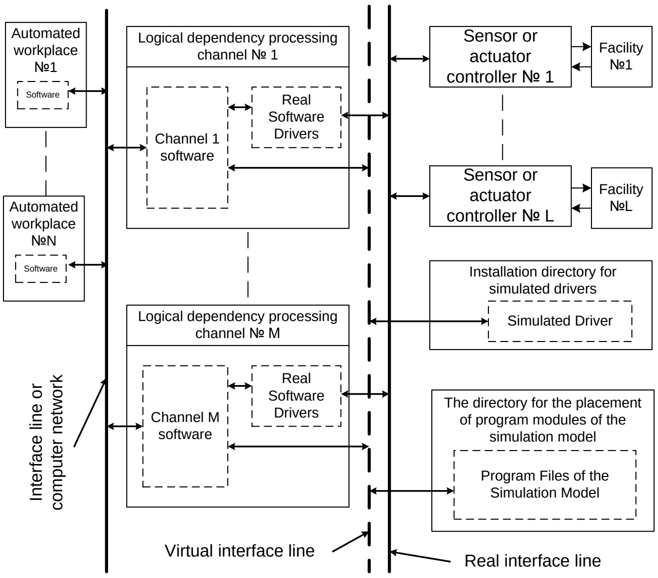

Fig. 6. Structural-functional diagram of the automated control system in conditions of interactive interaction with personnel

The interaction of the system with real sensors and actuators (or their object controllers) is performed on a real interface line. At the same time, the test actions of the technical diagnostics subsystem using the simulation model are implemented on the virtual interface line. The application software of the subsystem for processing logical dependencies does not distinguish between the corresponding lines (virtual and real). Thus, the simulation of failures in the process of technical diagnostics is performed identically to their actual manifestation for the system.

A more detailed scheme for organizing a virtual interface line is shown in Fig. 7.

Each interface module provides access to files and folders. The implementation of the virtual interface line is based on the complete identity of the structure of temporary files of real and virtual interfaces of drivers.

Use of the given simulation model is possible only after confirmation of its adequacy. Otherwise, it is impossible to achieve reliable results of technical diagnostics in the process of interactive interaction of personnel and equipment. Therefore, the adequacy of the model is proved by testing with subsequent comparison of the reference and actual results of its functioning. Only their complete coincidence guarantees the adequacy of simulation modeling.

The adequacy criterion is established both for a discrete automaton. At the same time, it is necessary to reproduce the fullness of the states of the sensors and actuators of the control system, as well as all associated technological situations [9].

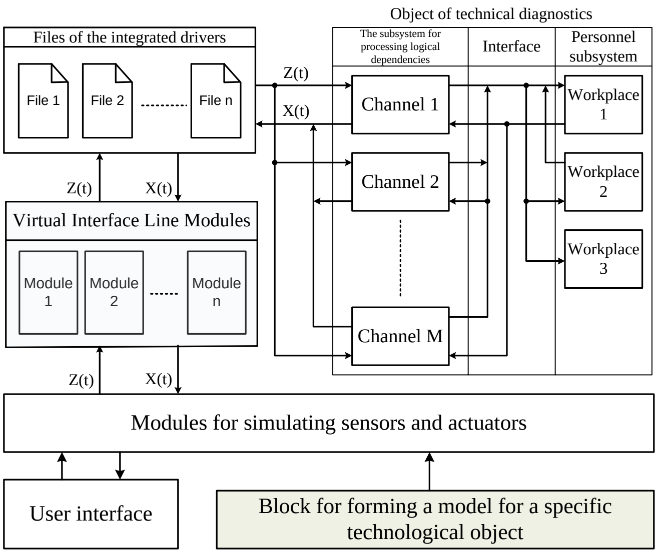

Fig. 7. The scheme for organizing a virtual interface line

In such conditions, it is possible to achieve the greatest safety of operation, taking into account the influence of the human factor both in the aspect of operation, and in the aspect of maintenance and repair.

4. Practical implementation

The proposed approach to the interactive interaction of operational, technical personnel with machinery, as well as control of the reliability of technical diagnostics, is experimentally introduced in the systems of microprocessor control of pointers and signals at a number of railway stations in Ukraine (Fig. 8) [10].


Fig. 8. Cabinet of the subsystem for processing logical dependencies of microprocessor interlocking of pointers and signals

For such systems, especially high requirements for functional safety and reliability are characteristic. This is connected both with the regulation of the passenger traffic, and with the transport of dangerous (including radioactive) cargo.

Therefore, the subsystem of processing the logical dependencies of microprocessor centralization is based on the majority reservation principle, within the framework of which the character of multichannel has not only hardware, but also software. This means that software development for each channel of the logical dependency processing subsystem is performed by different development teams under a single technical assignment.
Interactive interaction of the system with the operative and technical personnel is carried out by means of automated workplaces, tuning monitors and specialized maintenance stands.
At the same time, the technical means of diagnostics and its control are implemented programmatically – on the basis of the level of processing of logically dependent systems. Monitoring of the functioning of such an approach is carried out on the basis of an analysis of archival information, which is formed by the subsystem of recording the system's actions. After the end of the pilot operation, possible shortcomings and comments will be taken into account, after which the approach will be implemented on an ongoing basis.

5. Conclusion

Thus, new approaches to the interactive interaction of man and technology in automated control systems for responsible technological processes are proposed. Unlike the known, they assume an objective control not only of the operational factor, but also the maintenance and repair factor, as well as the control of the reliability of technical diagnostics. The introduction of approaches will significantly enhance the functional safety of the control systems used.

6. Literature

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