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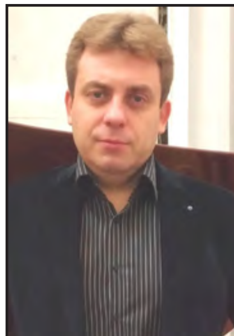
System of Remote Monitoring of Technical Objects





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ABSTRACT

Currently, digitalization, being implemented in all spheres of human activity, including transport processes, requires efficiency in obtaining and processing information, as well as timeliness of decisions made on its basis. The modern system of operation of railway traction rolling stock is characterized by the lack of online information about the current technical condition and the residual life of its components for decision making.

The article proposes to solve the problem by implementing an adaptive system for remote online monitoring of technical parameters of operated objects into the field of traction rolling stock operation. The adaptive system contains software related to recommendation decision support systems. A distinctive feature of the system is the presence of elements of artificial intelligence, which self-learns by combinatorial processing of the historical database on operation of this or a similar technical object and current performance indicators corresponding to them.

The proposed information processing algorithm is versatile and, in principle, can work with a variety of data sources, including existing traction rolling stock safety devices. Online monitoring of technical parameters of operated objects can be extended to both cargo-passenger rolling stock and related auxiliary machinery and devices (track machines, cranes, hump retarders, etc.). Based on the analysis of the information received, the software generates and transmits recommendations regarding current urgent actions for managing staff and maintenance personnel.

In addition, the proposed technology makes it possible to predict indicators of accidents at operated objects in real time, providing an opportunity to facilitate the diagnostic process, optimize organisation of maintenance, reduce the cost of maintaining rolling stock, and increase safety of the transportation process.

The adaptive system of remote online monitoring of operational safety of technical objects, considered in the article, through a risk-based approach, is a unique development that has no analogues.

Keywords: *railway, remote monitoring, artificial intelligence, safety, risk prediction, locomotives.*

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Background. The analysis of materials that determine the strategic prospects for development of the global railway transport industry shows that, all other things being equal, the key trend is associated with creation of the «Digital Railway» [1–3]. However, the process of transition to the unmanned technology should be a step-by-step process, through the evolutionary exclusion of a person from participation in the diagnosis process and subsequent adoption of a subjective decision. It should be borne in mind as well that the rolling stock in general and particularly traction rolling stock constitute key subsystems in the structure of railways.

So, for example, the strategy of scientific and technological development of Russian Railways holding company includes in its priority areas sections related to digital transformation of the holding company, i.e. creation of «Digital Railway» based on artificial intelligence methods, with a general focus on the use of Russian software and hardware [4; 5].

As for traction rolling stock in the context of this strategy, the requirements for it as an object of a digital railway are formulated, which consist in implementation of the «smart locomotive» technology. Moreover, when implementing online technology, conditions must be created that allow accumulating and analysing massive datasets transmitted from infrastructure facilities and the locomotive. All this, in turn, should create the possibility for prompt decision-making on operation of traction rolling stock and technological equipment [4].

However, implementation of online railway technologies, both in the Russian Federation and abroad, is associated with solution of a number of problems, the main trends of overcoming which were formulated in the materials of JSC Russian Railways [6]. The conclusions there-of can be supplemented by an analysis of locomotive maintenance systems performed by the authors [7].

Current situation in the field of operation and maintenance of traction rolling stock at the workshops of JSC Russian Railways is partially associated with delay in obtaining information about the technical condition, predicted malfunctions and the residual life of components of locomotive safety devices when a locomotive is delivered for scheduled maintenance and repair [6].

This is due to the fact that the main tools for ensuring safety of train traffic on the railway network of the Russian Federation and the CIS countries comprise integrated or local locomotive safety devices, for example, of «BORT», «CLUB» [integrated locomotive safety device], «SAUT» [system for automatic control of braking], «BLOCK» [integrated locomotive safety unit] types, etc. Such devices are installed onboard a locomotive and perform the following main functions:

• Receiving information about speed limits along the route.

• Getting coordinates of current location of rolling stock using signals from navigation systems.

• Continuous monitoring of speed parameters of the locomotive and implementation of emergency braking if necessary.

• Receiving information about railway signals to exclude passing signal at danger.

• Excluding uncontrolled movement of a locomotive.

• Monitoring work capacity of a locomotive driver, etc.

In most cases, the recorded parameters of the locomotive operation during operation are recorded on a removable storage medium, which, at the end of the trip, is handed over to the decoding unit of the locomotive operating (main) depot to which it belongs. After decoding data, the identified comments are entered into the automated system of traffic safety violations, which takes from 3 to 5 days, and then they are sent to specialists of production workshops, who develop information for the maintenance workers about the need for additional checks of locomotive components and units [6].

Obviously, this approach does not allow to quickly track failures in normal operation of traction rolling stock units and to eliminate the causes of a possible failure in advance. In fact, it turns out that traction rolling stock is sent for maintenance and repair after a fixed failure in operation of units, and not in advance, before its occurrence.

In such conditions, the risk of failure of the technical units of the locomotive is accompanied by the risk of damage from delays in train traffic, and if a failure occurs on the route, the consequences may be even more dangerous.

Analysis of the current situation, considering the requirements [6], allows us to highlight the

main features of a potential solution to the current problem of online monitoring:

• Reduction of time for identification, elimination and investigation of the causes of failures in operation of safety devices.

• Forecasting the probability of failure of a specific unit or part, depending on its current technical condition.

• Ensuring safety requirements for train traffic by preventing operation of traction rolling stock with potentially faulty devices.

• Reducing the number of failures and malfunctions in operation of locomotive units and safety devices due to their preventive maintenance.

• Automation of the process of collecting and analysing data obtained from rolling stock with subsequent development of recommended decisions for the maintenance personnel.

Thus, the essence of the problem being solved in relation to traction rolling stock is to increase traffic safety due to the predicted probability of a pre-failure state of locomotive units, assess risks of its further operation and generate recommended actions for its maintenance.

Based on the above, the process of finding a rational solution, obviously, should occur with respect to the following constraints:

• The relevant equipment should be installed onboard the traction rolling stock and provide continuous diagnostics of its condition.

• Software must be compatible with the existing traction stock control systems and automated systems of the transportation company that collect and process technical information about rolling stock.

• Traction rolling stock must be equipped with sensors.

• Implementation of online monitoring should not lead to an increase in maintenance personnel or the labour intensity of maintenance.

• In the current macroeconomic conditions, the proposed equipment should be highly competitive.

Results.

To solve the problem described above, an adaptive system is proposed that allows, using risk-based approach and IT technologies, to remotely monitor operational safety of technical objects [8–11]. It consists of hardware and software components ensuring collection information in a single database and in real time about:

• Current operational parameters of an object.

• Residual life of component parts of an object.

• State of local safety systems of an object itself.

• Likelihood of emergencies.

The proposed software belongs to recommendation decision support systems for managing technical objects and has elements of artificial intelligence, which self-learns by combinatorial interaction of the historical

Table 1

Accident risk assessment during operation of an object	Risk indicators	
Risk is acceptable: ordinary operation mode (green)		$u \le u_{min}$
Higher risk rate: operation should be performed under increased control (yellow)		$u_{min}<u<u_{max}$
High risk rate: operation is prohibited (red)		$u > u_{max}$

database on operation of this (or similar) technical object (including risk indicators of accidents) with the current operating indicators corresponding to them. It should be noted that the algorithm for calculating the risk of accidents is dynamically adjusted.

Based on the analysis of the information received, the software generates and transmits recommendations on current urgent actions for managing staff and maintenance personnel in the form of applications at their stationary and mobile devices.

All this, applied to traction rolling stock, allows in real time to:

• Remotely form an action plan for maintenance of rolling stock, depending on its current state.

• Carry out a daily linguistic check of operability of all monitored systems of rolling stock and transfer information to the database of the corresponding division and to mobile devices of drivers, dispatchers and managing employees with the possibility of visualization in the form of a scale of colour indicators.

• Automatically generate recommendations for assessing the probability of rolling stock accidents, depending on its current state, with transfer to relevant division of the organization.

• Collect information on violation of the requirements of regulatory documents by the maintenance personnel, provided for by the work and production instructions, with transfer to mobile and stationary devices of relevant divisions, drivers, dispatchers and managing employees.

• Process information from existing sensors and those additionally mounted onboard a rolling stock.

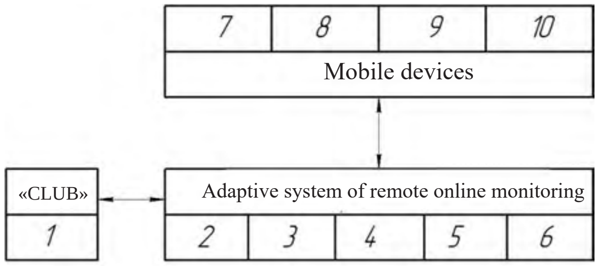
The algorithm and a set of criteria that characterize the safety rate of an object in time are adapted to databases that are updated in accordance with identified causes of accidents and incidents during operation of other objects. In other words, an intelligent system is being implemented that allows for transition from an unstructured multi-dimensional fuzzy space of indicators characterizing the current state of safety of an object to a single integral indicator in the form of a colour scale [9–12].

The limits of deviation of the current integral indicators from their «optimal» values are divided, for example, into three areas according to the predicted value *u* of the accident risk, using a scale of coloured indicators. If the values of the current indicators change within the area of optimal values, the predicted value of the risk indicator should move to the yellow zone ($u_{max} < u < u_{min}$), when the emergency values are reached, it is moved into the red ($u > u_{min}$) zone, and, accordingly, if there I no risk of an accident ($u \le u_{min}$) it is moved to the green zone. The indicator scale is shown in the Table 1.

To this it should be added that since it is not possible to cover the entire complex of diagnostic parameters characterizing operational safety of technical objects by monitoring sensors, then in linguistic diagnostics, the use of human intelligence becomes a key factor, that considers knowledge, skills, and experience of maintenance and supervisory personnel [9–12]. The developed measures provide an opportunity to compare the current information about the conditions of the selected object with data on emergency situations occurred with similar objects, as well as with changes made to the regulatory documentation.

Thus, a feature of the proposed system is the ability to integrate anthropomorphic and machine processes of collecting and processing information in real time using a set of algorithms based on neural networks, that is, using artificial intelligence technologies. The main result of the system is collection and analysis of all available information followed by risk assessment and development of information and recommendation support for decision-making by an operator [8–12].

The developed adaptive remote monitoring system is notable for its versatility and can be used in a wide range of industrial facilities,



Pic. 1. Diagram of interaction of software and hardware components of the safety recommendation system as applied to the locomotive: 1 – locomotive equipped with CLUB system; 2 – database; 3 – central server; 4 – website; 5 – software Web application; 6 – results of risk assessment in colours; 7 – locomotive crew (train driver instructor); 8 – inspector of the Traction directorate of JSC Russian Railways; 9 – factory inspector of the Centre of technical audit of JSC Russian Railways; 10 – inspectors of the regional and central structures of JSC Russian Railways.

including cable, road, water, air, and railway transport [13; 14].

Regarding traction rolling stock, the system can be used together with currently widely used domestic safety systems, for example, «BORT», «CLUB», «SAUT», «BLOCK», etc.

The main results of training neural networks based on the proposed technology and using linguistic and functional diagnostic criteria, regarding a locomotive equipped, for example, with a CLUB system [15], include:

• Increased reliability of remote control.

• Improved quality and timeliness of developing of recommendations for maintenance.

• Optimization of the maintenance process by predicting timing and labour intensity of planned maintenance of locomotives.

• General reduction of number of accidents during operation.

• Reduction in the number of personnel and inspectors and, consequently, in the cost of their wages.

The proposed technology will make it possible to ensure recognition of emergency factors associated with speed control, spontaneous movement, indication of signals, etc. in relation to various modes of movement (starting from rest, movement on main line, shunting mode, skidding, and slipping, etc.), and other indications of safety devices that are normally installed onboard a locomotive. The Pic. 1 schematically shows interaction of structural components of the proposed adaptive safety system, containing hardware and software.

This approach allows remote monitoring of locomotive devices using mobile applications, by constantly training the neural network using the historical data of CLUB complex devices, considering the dynamics of changes in these data during operation.

Thus, as applied to traction rolling stock, the proposed conceptual approach can be implemented to collect and analyse operational information about current and pre-failure states of locomotive components, as well as to assess the risk of their further operation, including the recommended actions for their maintenance. For example, a locomotive crew using linguistic and functional diagnostic criteria, according to the instruction (order No. 2070/r) [16], can assess the condition of an electric locomotive as part of its accepting after maintenance and repair works, namely:

• check the installation of elements of the brake and damping systems;

• inspect tightening of threaded connections in safety devices;

• check the presence of grease on wear surfaces;

• check operation of the pantograph;

• inspect the condition of traction electric motor and auxiliary systems;

• check operation of lighting and sound devices;

• check the presence of sand and operation of sand feeding devices;

• check the oil level in the traction transformer;

• check correctness of readings of work and emergency devices;

• check operation of the storage battery, etc.

The results of the check will be processed in real time and transmitted to the database of the central server of the system via the Internet.

Based on the foregoing, we can talk about the possibility of using this approach when applied to passenger wagons, multiple-unit trains, heavy track machines, hump retarders, etc.

The proposed technology was tested at the Caucasian Directorate of Rostekhnadzor [Federal Environmental, Industrial and Nuclear Supervision Service] when taking complex actions related to prevention of emergency situations at facilities of the second and third classes of danger, when monitoring the safety system on KB-408.21 tower crane. The crane was installed in the industrial park of LLC Master, owned by the PJSC KamAZ corporation. Thus, this technology has been tested on technical objects with different functional purposes and design.

Conclusion.

The adaptive system for remote monitoring of operational safety of technical objects through risk-based approach considered in the article is a unique domestic development that has no analogues [8].

The versatility of this control technology allows processing data from a wide range of industrial objects according to a given algorithm.

Regarding traction rolling stock, the proposed machine learning technology will improve the actual traffic safety by increasing the level of predicting the probability of failure of its units, assessing risks of its further operation and generating recommended actions for its maintenance.

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