PROTECTIVE FUNCTIONS OF LOCOMOTIVE INTELLIGENT SYSTEMS

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ABSTRACT

The article focuses on the questions of increasing efficiency and safety of operation of locomotives by reducing the human factor influence on train control. It is proposed to use intelligent decision support systems on board for partial replacement of a driver at the time of making controlling decisions that can protect against risks and threats, provided that those systems comply with technological and ecological modes. An outlook for most comprehensive of use of those systems in future aiming at larger replacement of a driver impact on decision making in such situations is considered.

Keywords: railway, locomotive crew, human factor, safety, intelligent control system, decision support, human ecology.

Background. *Modern locomotive is a complicated technical device, and in order to control it a driver needs an extended range of knowledge. To facilitate driver's work technical innovations are implemented such as on-board diagnostic systems, automated control systems of traction and of braking force, traffic safety control systems and others.*

Each generation of these systems is more and more expensive; traction rolling stock is becoming increasingly complicated. But if you look at how indicators have changed concerning cost of transportation, traffic safety, life cycle cost, the pace of their improvement has significantly decreased in comparison with the growth in financial expenses.

The conclusion is that the effectiveness of classical control systems and provision of locomotives' safety is close to its limit, and their further improvement will not lead to a radical change in the situation.

Objective. *The objective of the author is to study functioning of locomotive intelligent systems, particularly, in decision-making process and to analyze possible solutions to improve their efficiency.*

Methods. *The author uses general scientific methods, fuzzy logics, simulation, mathematical calculations.*

Results.

Onboard electronics oppresses a human

One reason for this situation is a limiting factor for the effective locomotive control, which is a human operator. Whatever automated systems are applied, no matter what part of monitoring and control functions they take, but the final decision on the transfer of a wheel controller for a particular position, actuation of brakes of the train, stopping or slowing down at traffic lights, etc. is taken by a driver. And here a so-called human factor comes into effect. Thus the quality of controlling decision (and therefore safety and efficiency of operation of the locomotive), despite the high level of automation and informatization of a train driving process, depends to a large extent on the psycho-physiological state of the driver, his level of knowledge and practical training, motivation, discipline, and other characteristics [1,2].

Thus, according to VNIIZhT algorithm of actions of the driver, while he is passing the stations in manual mode, witnesses the facts of exceeding permissible values of psychophysiological load indicators [3]. Analysis of survey data of drivers showed that when working in such a busy schedule early signs of fatigue appear within 3-4 hours, in contrast to the automatic driving mode where they occur only after 4-5 hours.

Automatic driving systems have been created and integrated into new series of locomotives, such as EP20, EP1M, 2ES5K and ZES5K, with on-board microprocessor control systems. To automate the suburban traffic abroad systems such as Cityflo 650 of Bombardier [4], Urbalis of Alstom company [5] and others are widely used. A certain disadvantage is in a considerable difficulty in the implementation of algorithms, which do not allow to accumulate experience and adjust their own control mode in order to improve performance shown during previous trips, that is a function of self-education is absent in those systems.

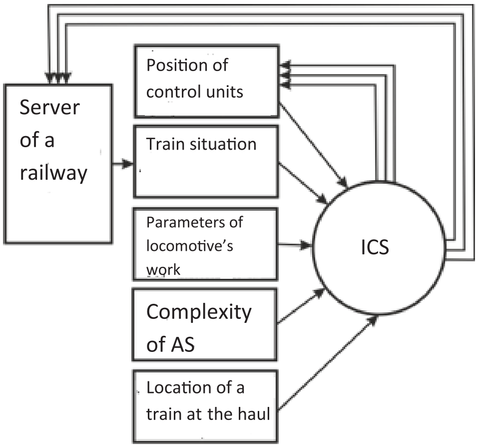
If previously a locomotive crew has been considered as a necessary control unit with the functions (simplified assumption) of: 1) train situation control; 2) making controlling decisions; 3) implementation of decisions by using isolated control units depending on the situation, then now there is a large set of developments that address the same tasks without human intervention. Modern electronics has long been able to effectively collect and process any information and put in place mechanisms of any complexity. In other words, the first and third paragraphs, bearing in mind functions of train control, are technically secured. The greatest difficulty is the remainder of the second paragraph concerning the scope of decision-making.

Modeling of intellectual functions

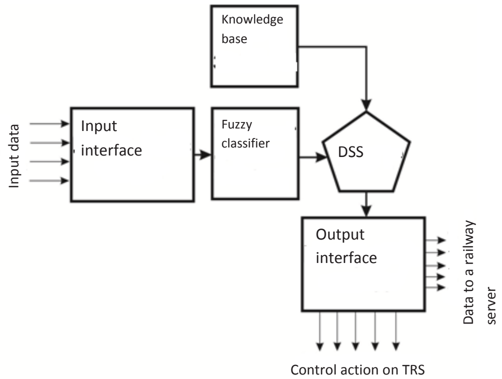
Development of artificial intelligence theory opens up opportunities for a fundamental change in approach to the control of traction rolling stock. It allows us to simulate the activity of locomotive crews during train driving. This will give a possibility to minimize, and in the future to opt out of direct human intervention in the regulation of locomotive movement.

The prospect of intelligent control systems (hereinafter referred to as ICS) for traction rolling stock is determined by several reasons. The first is that locomotive control based on conventional technologies cannot provide a substantial increase in efficiency of operation. Improving adaptive control algorithms results in significant complexity and implementation difficulties directly on board of the locomotive. It does not take into account a number of uncertainties affecting the system of «train–driver». Also, a precondition for ICS introduction is availability of a fundamental scientific basis [6,7], which can be used in conjunction with the theory of train traction and automatic control theory. Sharing this knowledge allows us to develop and effectively implement intellectual elements in the train driving process. And one more unquestionable cause of intelligent control technology of traction rolling stock (hereinafter referred to as TRS) is a dramatically increased level of informatization of all spheres of railway transport, availability of qualitative element base, widespread wireless data transmission systems.

The main advantages of ICS as compared to traditional:



Pic. 1. The scheme of information exchange for on-board ICS.



Pic. 2. ICS structure and a place of decision support system in it.

– The existence of a common knowledge base;

– The possibility of making decisions under uncertainty;

– Preconditions for self-learning;

– The possibility of integration into a single complex of traffic management across the region;

– TRS control with account for a comprehensive assessment of the effectiveness of the use of all transport vehicles within a given area (a section, a railway, a railway network).

However, ICS has some disadvantages, which are caused by the development of related technological areas: quality and prevalence of wireless communications in CIS is low, understaffing of existing locomotives with special equipment, lack of servers and software, the lack of systems for updating the knowledge of the staff.

If we consider global trends in intelligent technologies, it can be concluded that the greatest effect is obtained by combining the use of modern equipment with intelligent systems. With regard to railway transport, this means that the implementation of ICS must be provided during design and reconstruction of basic infrastructure facilities or vehicles. To equip outdated locomotives, dispatch centers, stations, traction substations and other with intelligent control system with a view to a long-term perspective is inappropriate. At the same time, by laying elements of ICS in newly designed large and costly transport facilities with an operation life of more than 25-40 years, industry corporation or company will create a solid base for a technical breakthrough in the future.

A scheme is proposed for designing on-board intelligent systems, which takes into account perspective model elements with intelligent load that help the drivers to protect themselves against potential threats to the working environment, including external (Pic. 1).

Efficiency of the system

One of the main elements of ICS (and, as noted, the most problematic) is a decision support system (hereinafter DSS), which provides a mechanism of responses to the challenge of the environment in the current situation (Pic. 2).

The main criterion for the work of DSS is usefulness of decisions made by the system. On the locomotive they relate to three central tasks: to drive a train with minimum energy consumption, minimal deviation from the timetable and most safely.

Let's represent a value of a action utility criterion in the form of the vector P $P(X_{AS}, G, \Delta t)$, where X_{AS} is predict ed complexity of abnormal situation (AS), G is predicted energy consumption (fuel), Δt is predicted deviation from the timetable (Pic. 3).

Predicted complexity of abnormal situation (X_{AS}) is a value which determines the degree of influence of various factors on its occurrence [8,9]. The calculation of these influences is produced using methods of fuzzy logic, which allows to identify the impact of a much larger range of factors and to formalize even those factors that are described only linguistically.

As the most useful action you need to take something that has a predicted value of $P(X_{AS}, G, \Delta t)=0$.

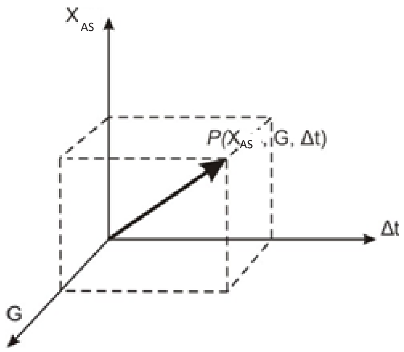
The calculations determined limit value of AS complexity at the level of 0,219. When this value is reached, abnormal situation should be considered dangerous. Therefore, in the algorithm of the intelligent system it is necessary to lay the function of testing values of X_{AS}. In the case, when its predicted value exceeds the limit, it is necessary to proceed to the calculation of other control action without determining P.

If in the calculation of the utility the same value of P will be for two or more control actions, it is advisable to implement the action that will ensure the minimum energy consumption for traction (taking action with minimal predictive value of G).

Ways to improve the accuracy and adequacy of the model is to reduce the time of forecasting and accounting of track profile, on which the train will be at the end of the forecasted period.

For practical application of the results of the calculation of the utility of decisions it is necessary that quantities characterizing fuel consumption, complexity of AS and deviation from the timetable have the same dimension. This is easy to achieve with the transition from absolute to relative values as coefficients. But for higher information content of calculation results it is offered to transfer these parameters into cost equivalent. In simplified form, the objective function of decision-making for locomotive DSS looks like this:

$$|P| = \sqrt{\bar{W}^2 + B_F^{\ 2} + B_S^{\ 2}} \Rightarrow \min ,$$



Pic. 3. Graphical determination of efficiency.

where $|P|$ is criterion of the usefulness of a made decision as a minimized norm of a vector;

$\bar{W}$ is mathematical expectation of losses from the accident (obtained on the basis of risk theory with the use of AS complexity parameter), c.u.;

B_F is predicted fuel costs (electricity) over the forecast period, c.u.;

B_S is predicted losses from the failure to schedule, c.u.

Thus, the essence of DSS is as follows. The system receives external data on the conditions in which the controlled train is located through input interface (Pic. 2) and a fuzzy classifier, which has the task to describe these conditions in a representative form. Then there is a comparison of existing situation with a set of options for train conditions stored in the knowledge base. DSS chooses a certain number of rules from the knowledge base and calculates the usefulness of each of them. That rule, the control impact of which will be as useful as possible in the circumstances, is used by on-board ICS by the action directly on locomotive control units, or by issuing recommendations for the driving a train to locomotive crew.

Conclusions. *Application of developed approaches to locomotive ICS assumes significantly improving operational efficiency of TRS. It is expected that the direct effect of reducing the consumption of energy (fuel) for traction power will be from 0,3% to 1,6% due to a better control, which minimizes the risk and the human factor influence. In addition, traffic safety is increased by monitoring the train situation in the whole area (movement of trains moving before and after the given train, position of signals on several hauls ahead, constant speed control with account for warnings, assessment of ecological conditions and so forth) via the connection to the railway server.*

With large-scale implementation of ICS at the railway (or railway network) it becomes possible to solve problems such as flexible optimization of a schedule, more rational use of the complex of electrical substations, switching to locomotives driving by one person, and so on. One cannot ignore the ability of intelligent systems to be tuned in future to more comprehensively control of parameters related to human ecology, as well as to natural and urban environment.

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