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DEVELOPMENT OF INTELLIGENT CONTROL SYSTEM FOR LOCOMOTIVES

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Abstract: *The development of the theory of artificial intelligence opens up opportunities for fundamentally changing approaches of the traction rolling stock operation. And another reason for the development of intelligent control technology of traction rolling stock (TRS) is the level of Informatization in all the spheres of railway transport, qualitative elements, a widespread system of wireless data transmission, and special software. One of the most important elements of the ICS is an intelligent agent, providing a mechanism for making decisions in the current situation. The main criterion of intelligent agent (IA) is the usefulness of its decisions. IA working as a part of the ICS on the locomotive must achieve the following main objectives: to conduct a train with minimal energy waste, with minimal deviation from the traffic schedule, most safely. In this paper was obtained the model of IA efficiency calculation. Application of the developed approaches in the implementation of ICS by locomotives will significantly improve the TRS operation efficiency.*

Key words: *text intelligent control, traction rolling stock, traffic safety*

1 INTRODUCTION

A modern locomotive is a complex technical device for which locomotive crews often need a wider range of knowledge. To improve the locomotives operation efficiency and facilitate the work of staff a number of technical innovations such as modern on-Board diagnostic systems, traction and braking automated control systems, traffic safety control system and others are implemented. Each generation of these systems is becoming more expensive, traction rolling stock is becoming more complicated. But if you look at how the performance of transportation cost, traffic safety, life cycle cost changed you can see their improvement rate declined significantly compared with the rate of the growth of financing for the mentioned systems implementation. Thus, it is possible to conclude that the effectiveness of classical control systems and locomotives security has recently approached its limit and further improvement will not result in a significant effect. At the same time, the cost of implementing these measures increases very significantly.

The reason for this lies in the fact that the limiter of the modern locomotive operation efficiency is a human operator. Whatever automated systems were used on locomotives, whatever part of the control functions is done by them, but the final decision on transferring controller steering wheel for any position, e.g. train braking, speed stopping or reducing in front of the traffic lights, etc. is made by the driver. And here so-called human factor comes into effect. The quality of accepted administrative decisions (and therefore the safety and effectiveness of locomotive operation), despite the high level of automation and informatization of train running, mostly depends on the engine driver's physiological condition, his knowledge level and practical training, motivation, discipline and other characteristics[1,2].

If earlier a locomotive crew was considered as a necessary management body with such functions as (simplified): 1- traffic condition control, 2- management decision- making, and 3-implementation of decisions by affecting disparate management bodies depending on the situation, now there is a large stock of developments to tackle these tasks without human intervention. Modern technology has already allowed to collect and process any information efficiently, to actuate the mechanisms of any complexity, i.e., the first and third paragraphs on the train operation are technically solved. The greatest difficulty is the second paragraph relating to the decision-making.

2 METHODS, PRINCIPE APPLIED IN RESEARCH

The development of the theory of artificial intelligence opens up opportunities for fundamentally changing approaches of the traction rolling stock operation. It allows simulating the activities of locomotive crews during running of the train. This will make it possible to minimize, and in the future to opt out of the person participation in the rolling stock operation.

The prospect of intelligent control systems (ICS) for traction rolling stock has several reasons. The first one is that the locomotive operation on the basis of traditional technologies cannot provide a substantial increase in the operation efficiency. Improving adaptive management leads to considerable complexity and difficulty of its implementation on the locomotive board. And a number of uncertainties affecting the system "train and driver" are not taken in consideration. Also the prerequisites for the implementation of the ICS are based on the fundamental scientific basis [3, 4], which can be used in conjunction with the trains traction theory and the theory of automatic control. Sharing this knowledge allows us to develop and effectively implement intellectual elements in the process of driving trains. And another reason for the development of intelligent control technology of traction rolling stock (TRS) is the level of Informatization in all the spheres of railway transport, qualitative elements, a widespread system of wireless data transmission, and special software.

The main advantages of locomotive ICS compared to traditional ones are:

the presence of a common knowledge base;

the possibility of making decisions under uncertainty conditions;

the ability of self-learning;

the possibility of integration into a single complex traffic management in the region;

the ability to manage TRS from the point of view of a complex estimation of efficiency of use of all means of transport in this area (a railroad haul, railroad, railroad network).

However, the ICS also has some disadvantages which are caused by the development of related areas of technology: quality and the prevalence of wireless communication in the

CIS are low, the necessity of equipping the existing locomotives additional equipment, the need for additional servers and software, specialized staff training.

If we consider the global trends of intelligent technologies application, we can conclude that the greatest effect is obtained combining the use of modern equipment with intelligent systems. Regarding rail transport it means that the implementation of the ICS should be considered while designing and reconstructing basic infrastructure or vehicles. To equip the outdated locomotives, control centers, stations, rectifier substations and others with intelligent control systems for a long term is not appropriate. Large and expensive transport facilities are designed for more than 25 - 40 years, and implementing ICS elements now a substantial basis for the technological progress will be created in the future.

For the design of on-Board intelligent systems the scheme shown in figure 1 is proposed.

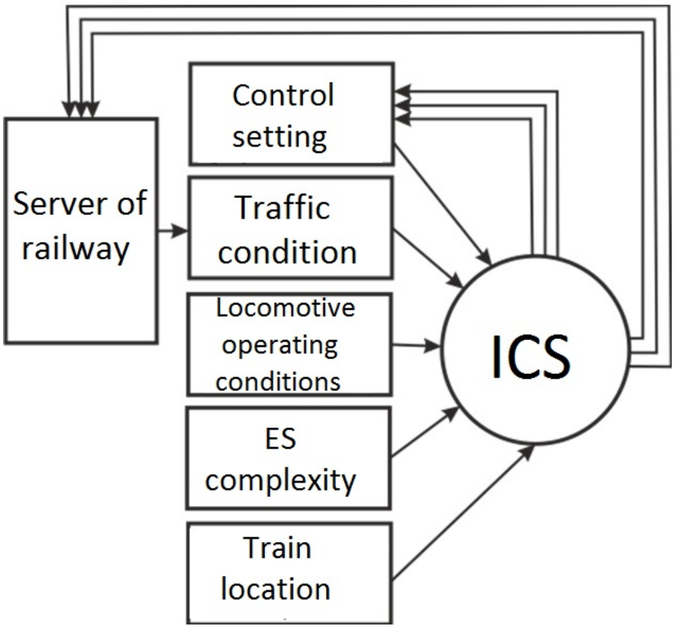

Fig. 1 - on-Board ICS information interaction scheme

One of the most important elements of the ICS is an intelligent agent (figure 2), providing a mechanism for making decisions in the current situation.

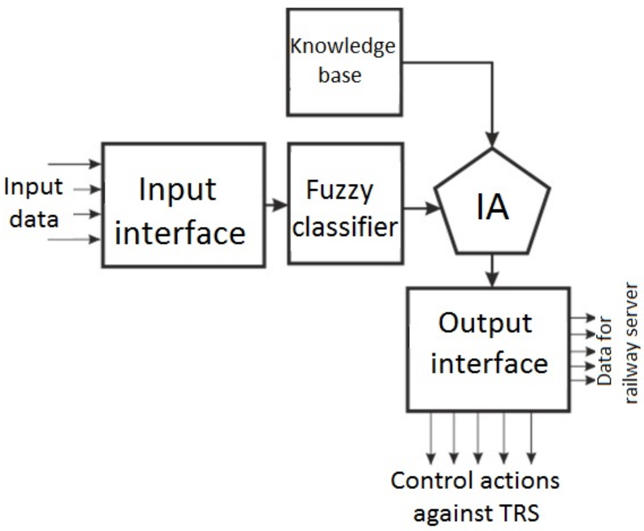

Fig. 2 - ICS structure

The main criterion of intelligent agent (IA) is the usefulness of its decisions. IA working as a part of the ICS on the locomotive must achieve the following main objectives: to conduct a train with minimal energy waste, with minimal deviation from the traffic schedule, most safely.

3. DESCRIPTION OF SOLUTION

Imagine the magnitude of the efficiency criterion as a vector P (X_{ES}, G, Δt) in figure 3, where X_{ES} - forecast complexity of emergency situation (ES), G - forecast energy(fuel) consumption, Δt is the forecast deviation from the schedule.

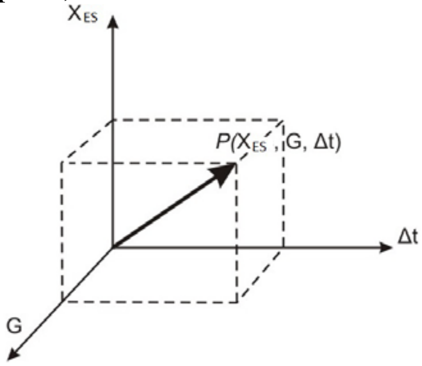

Fig. 3 - Graphical determination of the efficiency.

X_{ES} is the value that determines degree of various factors influence on the occurrence of ES[5,6]. The calculation of these effects is produced using methods of fuzzy logic, which allows to identify the impact of much larger range of factors and to formalize even those that are described only linguistically.

As the most useful steps you need to take that in which the forecast predicted value P (X_{ES}, G, Δt) =0. As a result of calculations the limit value of the ES complexity on the level of X_{ES}=0,219 was determined. When this value is reached, the ES should be considered dangerous. Therefore, the function to check the value of X_{ES} should be provided in the algorithm of intelligent systems. In the case where the predicted value of X_{ES} exceeds the limit one, we must proceed to the calculation of other control actions without identification of P.

If the value for two or more control actions will be the same when calculating the utility, it is advisable to implement the action that will ensure minimum energy consumption for traction (action with the minimum predicted value G).

The simplest algorithm for determining the efficiency of train operation IA is the calculation under the following conditions:

- the efficiency is calculated for a specified forecast period (not exceeding the time of the train emergency braking), before this period being over, the agent does not take decisions;
- the efficiency is determined by assuming that the running conditions will not change until the end of forecast term;
- the efficiency is characterized by a distinct number;
- the track profile on the section situated after calculated one is ignored.

General view of the IA efficiency utility calculation is as follows:

$$X_{ES} = f\left(X_{HF}(T_{pd}); X_{TF}(T_{pd}); X_{EF}(T_{pd})\right),$$
$$G = G_i \cdot T_{pd},$$
$$\Delta t = s/V_{sh} - s/V_a,$$
$$P = \sqrt{X_{ES}^2 + G^2 + \Delta t^2} \qquad (1)$$

where X_{ES} - the complexity of ES;

X_{HF}, X_{TF}, X_{EF} - values which assess the human, technical and external factors influence on the complexity of the ES;

T_{pd} – the time which is predicted when calculating the particular control action utility;

G – predicted value of energy (fuel)consumption;

G_i – consumption of energy (fuel) per unit of time in a predicted mode of train driving;

Δt – the predicted value of the deviation from the schedule;

s – the distance remaining to take the train to the control point (station, switching track, kilometer, and so on);

V_{sh} – the speed which is in the schedule;

V_a – actual speed;

P – the utility criterion of calculated control decision.

The identification of the efficiency under conditions mentioned above is not quite accurate. The ways of improving the accuracy and adequacy of the model is the introduction of additional points between the current time and the predicted time T_{pd}, and the profile of the track at which a train will be at the end of the predicted period.

For practical application of the expression (1) it is essential that the quantities characterizing the fuel consumption, the complexity of the ES and the deviation from the schedule have the same dimension. This is not difficult to achieve it with the transition from absolute values to relative ones in the form of coefficients. But for more informative results of the calculation conversion of these parameters into the cost equivalent is proposed. Then, considering ways to improve the accuracy of calculations, we obtain the following model of IA efficiency calculation

$$P = \sqrt{\overline{W}^2 + B_f^2 + B_{sh}(\Delta t)^2} \Rightarrow \min \qquad (2)$$
$$T'_{pd} = T_{pd}/n, \ if \ 1 \le n \le T_{pd}/T_{tcmin},$$
$$X_{ES} = f\left(X_{HF}(T_{pd}); X_{TF}(T_{pd}); X_{EF}(T_{pd})\right),$$
$$\overline{W} = X_{ES}(T'_{pd}) \cdot w$$
$$G = G_i \cdot T'_{pd}, \text{ when } F_{ct} \in (f_{av}, \alpha', \beta') = \frac{4.17((v_e'^2 - v_s^2), \alpha^2, \beta^2)}{s} + w_{av}$$
$$B_f = G \cdot b_f,$$
$$\Delta t = s/V_{sh} - s/V_a,$$
$$B_{sh}(\Delta t) = B_l + B_t + B_c,$$

where T'_{pd} – estimated predicted period;

T_{tcmin} - minimum time between the change in the mode of conducting train (transferring controller's lever, actuating brakes, etc);

n – coefficient indicating how many spaces the forecast period should have for further calculation in these terms;

$\overline{W}$ – mathematical expectation of losses after traffic accidents, $;

w – estimated loss after traffic accidents, $;

b_f – fuel cost - $/kg or electricity $ /kWh;

B_f – fuel (energy) cost in the predicted period, $;

B_l, B_t, B_c – the cost of locomotive-hours, the train-hours, crew-hours which are out of schedule respectively, $;

B_{sh} – cost of the default schedule, $;

F_{ct} – the current value of the locomotive tangential traction control, kN;

v_e' - projected final speed of the train on schedule, km/h;

(f_{av},α',β') – the average value of the tangential traction control, which is necessary for train running along a given section(in the form of fuzzy number L-R-type with α'-left and β'-right fuzziness ratios, kN.

Thus, the essence of the IA work is the following. IA receives external data about the conditions in which a running train is by the input interface (Fig. 2) and fuzzy classifier, its task is to describe the conditions which are acceptable for the agent perception. Next is the comparison of the existing situation with a set of train conditions choices stored in the knowledge base. IA selects a certain number of rules from the knowledge base and calculates the utility of each of them. Some of the rules governing impact of which will be of maximum utility in these terms are applied by on-Board ICS impacting directly on the locomotive operation, or giving locomotive crew guidelines on the train operation.

4 CONCLUSION

Application of the developed approaches in the implementation of ICS by locomotives will significantly improve the TRS operation efficiency. We expect direct effect in the form of energy (fuel) consumption reduction for train’s traction in the amount of from 0.3% to 1.6% due to more rational management, which minimizes the human factor influence. In addition, the safety degree is assumed to increase by taking into account the train situation in the whole section (the traffic in front of and behind the running trains, the signals position a few lengths ahead, the constant speed control with regard to warnings, etc.) through communication with the track server. Implementing IMS on the track (or track network) there is also possibility of solving such problems as flexible optimization of the schedule, more rational using power substations, the opportunity to maintain locomotives by one person in the train operation, optimization of shunting stations, etc.

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