THE FUTURE OF RADIO CONTROLLED SWITCHES WITH AUTONOMOUS POWER SUPPLY

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ABSTRACT

A promising control method for railways, that takes into account minimization of the number of outdoor technological facilities, use of wireless data transmission technologies, as well as use of renewable energy sources for decentralized switch systems is considered. It is proposed to implement all other commands through the use of cyber-protected radio channel while renouncing to discrete positioning of mobile units and discrete transmission of data on the speed patterns of train movement. The system of switches with autonomous power and use of a radio channel to manage and control the position of switch blades must be adapted in stages, starting from the local level and basing on availability of portable devices and going to comprehensive centralised control system within the station.

Keywords: railway, traffic control, digitalization, alternative energy sources, radio channel, railway switches.

Background. *Development of rail transport throughout the world is keen on creating high-speed competitive transportation, as well as on improvement of operation of infrastructure and of rolling stock, in order to optimize the use of resources. In this regard, attention of the railway community is focused on intellectualization and digitalization of the transport process with the transfer of a significant part of control and diagnostics functions to mobile traction units [1–5].*

Objective. *The objective of the author is to consider different aspects related to the development of switches, autonomously powered and controlled by radio channels.*

Methods. *The author uses general scientific and engineering methods, comparative analysis, evaluation approach, scientific description.*

Results.

There should be an alternative choice of each step

Digitalization will fully allow to take into account goals and objectives of all participants in rail transportation, optimize the loading of infrastructure facilities, rolling stock and operators (both traffic control centers, stations, and drivers), as well as to pave way to create smart and energy efficient rail transport [6, 7].

Digitalization is only one side of development. The second side is solution of the energy problem. It is a well-known fact that humankind now receives the energy mainly through the use of non-renewable energy sources. Railway transport uses almost exclusively the non-renewable sources. The energy efficiency in the industry is extremely low, the energy loss is high during technological processes, and the efficiency factors (EF) are far from ideal ones (for example, the efficiency of electric traction, which takes into account similar indicators of power plants, devices of external and traction power supply, electric rolling stock, is less than 25 % [8]). In addition, a significant disadvantage of traditional energy sources is caused by harmful emissions and a destructive impact on the environment [9, p. 87].

Many countries pay attention to the global problems of non-renewable energy, the cost of resources, the impact on the environment and the world ecology. This also applies to railway networks. So, for example, the railways of the Netherlands (NS et al.) since 2017 mainly use sources of renewable energy (wind energy), and Denmark aims to finish transition to the use of only renewable energy in the railway complex by the middle of 21st century [10]. The developing countries of the Asian continent, primarily Japan and India, use the energy of the sun, having solar panels on the roofs of the platforms at stations and wind turbines along the railway stations, including those controlled by the wind load from a moving train [11, p. 1; 12, p. 1; 13, p. 1; 14, p. 25].

Studies on the designated topic are being conducted in the European countries [15, 16]. Some works in the field of generation of alternative energy generation systems are published by engineers and scientists from the post-Soviet countries [17], in particular, they concern the field of train traffic control [18]. The top management of the Russian railways also shows its growing interest in this issue [19].

It should be noted that there are opponents of renewable energy sources, expressing reasoned doubts about their use at this particular stage of development. Academician P. L. Kapitsa also spoke out against alternative energy in 1975 [20, pp. 40–41].

Railway transport in Russia, in fact, does not use the possibilities of renewable energy sources. Rare positive examples include perhaps the distributed systems for technical diagnostics and monitoring of complex engineering structures, like a railway contact suspension: in such a system [21, p. 22] solar panels increase the service life of diagnostic devices operating from autonomous power sources. The relatively low cost of electricity production is the main argument against the practice of using renewable energy sources in Russia [10].

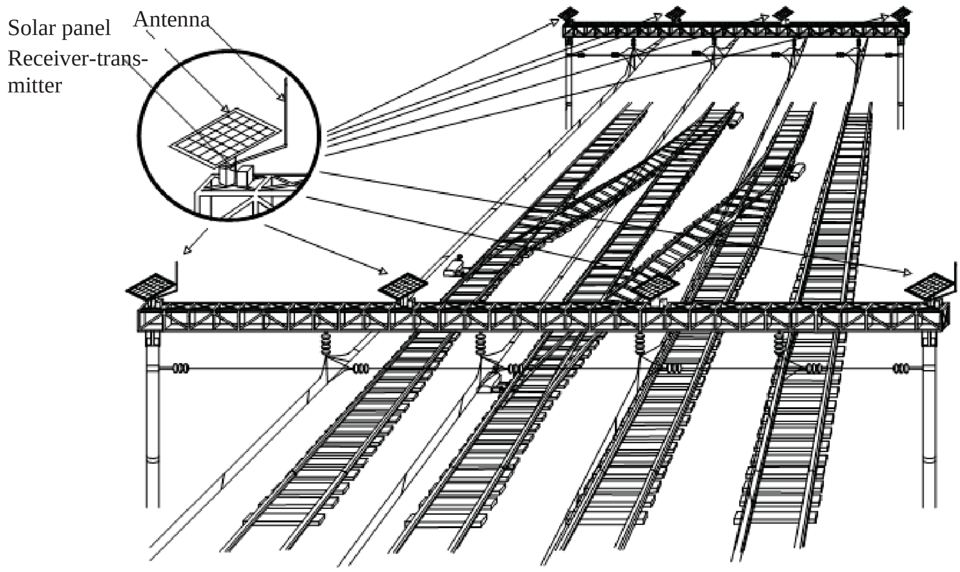
Despite all the difficulties of adapting renewable energy sources to the specifics of railway facilities, the world community is increasingly drawing attention to them as a likely alternative to traditional methods of energy supply in the near future. One of the possibilities of the use of renewable energy is related to train control systems.

Divide and manage

Railway traffic control systems are a combination of stationary means and devices located in close proximity to the roadway and in many cases using it as a data transmission path, as well as portable or on-board control devices for traction units [22, p. 20]. Nevertheless, the world railway community is already actively drawing attention to the need to change the principles of train traffic control.

The main stationary means of positioning of mobile units are track chains (invented in the second half of 19th century), as well as axle counting systems. And the first ones are widely used on the railways of the former Soviet Union. The above mentioned means assume positioning within one section, equipped with a track circuit or limited axis counting system. The prospect of development of positioning sensors for mobile units is gradual elimination of very unreliable track circuits and the use of axle counters; in the longer term, satellite positioning is possible.

Basically, the function of controlling train movement is performed by signaling systems and



Pic. 1. The location of the elements of power supply on the infrastructure of traction facilities.

devices, which include a variety of traffic lights (they were invented at the beginning of 20th century) and sound signal sources. Information to the driver about the speed modes and the number of forthcoming free areas of control of mobile units is transmitted as a light signal. It arrives at the stationary (floor) traffic light of the control area, to which it is allowed or not allowed to enter, as well as at the on-board (locomotive) traffic light. To receive color signal data on a locomotive, sections of railways are equipped with automatic signaling with light code encoding with a special code. This method of positioning of mobile unit serves for regulation of movement within the stationary areas with low grading of speeds.

The possibilities of modern wireless communication allow organizing the so-called «mobile» block sections when the train itself is the central object of movement, and the on-board equipment receives data in real time on all permissible movement parameters of the mobile units that are either in front or behind that train [23, p. 363; 24, p. 227]. The prospect of development of signaling systems is elimination of the traffic light system and the use of direct instructions to the driver about the speed of train operation (up to automation of this function). For all that, the main disadvantage of traffic lights is presence of a deployed and distributed cable network running along the tracks and stations.

Railway switches serve as a tool of implementing various technological processes at stations associated with the need to separate trains, to free the tracks for their movement, etc. They allow the movement of rolling stock on various tracks and change the trajectories of their movement. Among all stationary controls on the rail transport in the future, only switches will be retained, as well as mechanisms for their transfer between their extreme positions.

However, at the present time, all the designated traffic control means are included into the cable network, both control and power supply are predominantly centralized. Traffic control is carried out by means of electrical interlocking systems with separate or integrated interval control systems on the hauls.

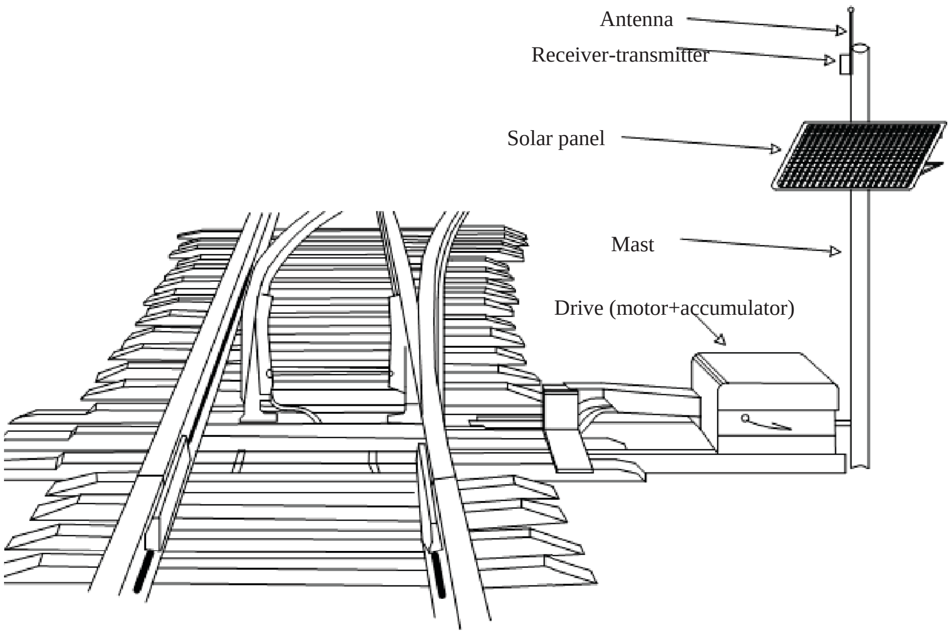
The prospect of preserving only railway switches as means of implementing technological processes leads to the fact that the most urgent task is development of such a control system for switches that will operate with minimal cable consumption while organizing guaranteed safe train passage. In this context, it can be a question of switch-centralization systems with introduction of analogs of routed movement without traffic lights with accurate positioning of mobile units (not within the discrete areas of control).

Autonomously powered switch actuators

The main element of the railway switch control system is the switch actuator that moves the switch blade (or other elements of its structure, for example, the switch diamond) from one extreme position to another. All other objects of the floor technological equipment may well be eliminated during the evolution of automation systems [22].

The number of switch control elements is determined based on the technological features of the stations, the presence of flat switches on it, the need for additional actuators, etc. [25, p. 31]. But one switch is usually controlled with a single drive. In addition, the switches can be provided with safety devices (derailing shoe), which are also controlled by separate actuators. Thus, most often at intermediate stations there are up to 30 switches, and at the largest, naturally, there are more – up to 100 and more. Due to the small number of controlled objects, the construction of a system with a developed cable network is economically inexpedient, the same is true for the subsequent operation of such systems. This is especially true for stations where it was decided to transfer the control of switches from manual to automatic mode.

The problem arises to create such a complex of control of railway switches, that would include devices that allow to drive switch blades, located in close proximity to the switch itself. In this case, the switch must have not only the drive, but also the



Pic. 2. The location of elements of construction of the railway switch control system.

means of its power supply, as well as of tranfer of information to point of control, and of transfer of information about reaching of the extreme position of the switch. It is clear that power supply sources do not intend to use an extended cable network. This option is already being worked out, for example, on the railways of Sweden for modernization of the manual control of switches.

There are several solutions of the presented problem.

The first is to create a distributed energy generation system and cover the station with renewable energy sources that can be located on roofs and platforms or mounted on structural elements of a railway contact network (Pic. 1). To this end, the elements of supporting network structures are being upgraded to secure energy sources on them. Moreover, it is required to provide energy storage in special accumulative subsystems, in places designated for this purpose along the railway tracks, and there is a need for cable linkage with automatic control devices for railway switches. In this case, it is convenient to transmit all control and monitoring signals by cable to the receiving and transmitting points in close proximity to the antennas of the information transmission organization system. The station itself in such a situation is an information space covered by the industrial Internet of things (IIoT) [26, p. 1], functioning in accordance with all the requirements on cybersecurity [27, p. 29].

Another solution of the task is creation of decentralized control subsystems for each railway switch separately (Pic. 2). Such a subsystem is supplied with an alternative energy source, which is fixed on its mast at a sufficient height to ensure anti-vandal resistance, as well as means of energy storage and data transmission.

This technical solution is convenient for stations with a small (up to 30) number of switches and a relatively small workload.

The complexity of building a railway switch control system is as follows:

1. It is necessary to determine sufficient (taking into account the reserve) power capacity to ensure functional tasks.

2. To save energy, the survey of receiving-transmitting devices should not be carried out continuously, but when the state of the railway switch needs to be changed, or if changes occur in emergency situations (sensors are needed that record these events). At the same time, to ensure safety, monitoring of the current state of control devices is required.

3. Creation of own Internet of things, closed for any access, is required.

4. It is necessary to organize the linking of the central positioning system of mobile units at the station to the railway switch control system through the radio channel.

The indicated problems have not been fully resolved yet, but they are partially solved in the systems of manual local switching of points (for example, in Siemens versions for railway depots) [28, p. 9]. And the stage of transition to a wireless motion control system should take place in stages, with minimization of the floor-standing objects of the railway infrastructure.

Conclusion. *The development of technology and equipment in the first quarter of the 21st century suggests the possibility of fundamental changes in the field of control systems in railway transport and the renunciation to the traditional, uninformative control systems with discrete positioning sensors of mobile units, traffic lights and advanced power supply and data transmission networks. Two key trends are of great importance in this issue: «intellectualization and digitalization» and «development of smart energy supply systems». Both directions should be developed in parallel, with the goal of optimizing the costs of implementing technological processes for safe control of train traffic on railways.*

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