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Integration of Control and Monitoring Systems

Efanov, Dmitry V., *LLC LocoTech-Signal, Russian University of Transport, Moscow, Russia*.*

Dmitry V. EFANOV

ABSTRACT

Stationary systems for monitoring devices of train traffic control are currently being implemented as external means of technical diagnostics and are located mainly centrally. The set of diagnostic parameters is scarce, and most measurements are indirect. This, ultimately, leads to low efficiency of monitoring systems, and the share of useful information from the total amount of data according to experts does not exceed 5 %. The development of monitoring technologies should follow the path of integration of measurement and control functions. The objective of the work is to draw the attention of the scientific community to the principles of monitoring and control systems implementation and the transition from their disunity to integration. Using methods of technical diagnostics and monitoring, it is proposed to switch to more advanced control systems with built-in means of troubleshooting and monitoring. The author has proposed the concept of integrated technical diagnostic tools with object controllers in the form of removable monitoring modules that transmit data along dedicated diagnostic transmission paths. Depending on the geographical location of the controller (centralized at the control station or decentralized near the controlled object), a set of diagnostic parameters is determined and a choice of diagnostic information processing methods is carried out. With decentralized location of controllers, the diagnostic modules can transmit diagnostic information from external and distributed sensors at railway infrastructure facilities. Implementation of the presented concept will allow receiving a much larger amount of initial data for operation of monitoring systems, including transition to obtaining digital twins of railway infrastructure facilities. In a broader sense, when organizing monitoring systems, it is necessary to focus not only on railway automation, but also pay attention to other infrastructure facilities serviced by personnel of adjacent sectors. Since all objects function together, such an approach to organization of monitoring will improve quality of diagnosis and prognosis, as well as provide an opportunity to assess the residual resource of technical objects.

Keywords: *transport, technical diagnostics, troubleshooting, monitoring, integration of measuring and control functions, diagnostic data, railway infrastructure facilities, digital twins.*

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*Information about the author:
Efanov, Dmitry V. – D.Sc. (Eng), Associate Professor, Head of the Direction of Systems of Monitoring and Diagnostics of LLC LocoTech-Signal, Professor at the Department of Railway Automation, Remote Control and Communication of Russian University of Transport, Moscow, Russia, TrES-4b@yandex.ru.

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Background. Methods of technical diagnostics [1–6] are widely used at all stages of the life cycle of devices and automatic control systems. At the stage of development of a device or a system, for example, this is expressed in testing and verification of hardware and software components, in choosing and justifying a method for implementing subsystems of internal control and diagnostics, etc. [7]; at the operation stage, this is associated with periodic testing and functional diagnostics of blocks and components, monitoring the technical condition of external-connected devices, maintenance with the assistance of service personnel [8]. Without the use of embedded and external technical diagnostics and monitoring, it is impossible to implement the concept of a digital railway [9].

In recent years, built-in technical means of diagnosing and monitoring the state of engineering structures and units have become widespread in all industries and transport. In order to increase their fault tolerance, prevent accidents and disasters, specialized measuring devices are connected to the objects of diagnosis, transmitting the received diagnostic data via a wired (and, much less commonly, wireless) transmission path to concentration and processing devices. This makes it possible to interrogate the sensors of measuring devices with a certain predefined period and form diagnostic data arrays in the monitoring system software, as well as analyze the received data. Based on the analysis, informational messages are generated, trends of deterioration of operating parameters are identified, and service employees are alerted.

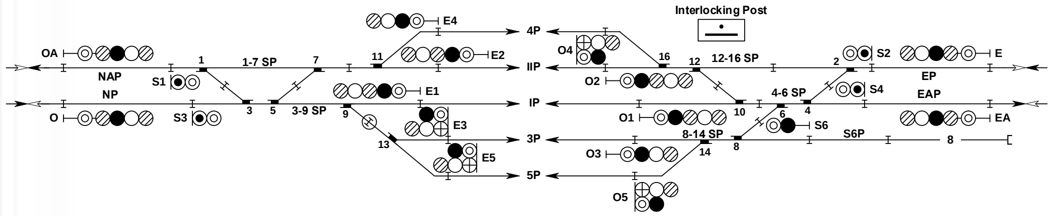
At the initial stage of developing a system of technical diagnostics and monitoring, a controlled object is examined, in some cases a mathematical model of this object is created, and connection points for sensors are selected to ensure the required completeness and depth of diagnosis. The volume of diagnostic parameters directly affects quality of the monitoring procedure, accuracy and timeliness of diagnosis and subsequent solution of the forecasting problem.

The *objective* of this work is to draw the attention of the scientific community to the principles of monitoring and control systems implementation and transition from their autonomy to integration. Using methods of technical diagnostics and monitoring, it is proposed to switch to more advanced control systems with built-in means of technical diagnostics and monitoring. Directly in this article, a conceptual technical solution was proposed for improving technologies for diagnosing and monitoring devices and systems for controlling movement of trains taking into account their features [10; 11].

Monitoring of control devices

The set of devices and systems for controlling movement of trains includes various devices of railway automation and is intended to automate control procedures for technical means regulating movement of trains and, in particular, transferring data to on-board automation equipment of traction moving units. The main objects of control and monitoring for railway automation systems are floor technological facilities, the automation equipment, which is located in close proximity to the railway track and for some devices are even integrated with rails (we are talking about rail circuits). The main outdoor objects of railway automation include devices for automatic switch of arrows (turnout electric drives), devices for transmitting signals to the driver (traffic lights), devices for positioning moving units (rail circuits). According to statistics, these devices account for up to 80 % of failures of all railway automation devices [12, p. 4]. In addition, outdoor equipment of railway automation, as a rule, is devoid of built-in technical diagnostics, and the vast majority of its components are not redundant [11]. Failures of floor processing equipment have a very negative effect on the transportation process and can directly affect train traffic failures and irregularities in train schedules. Therefore, the main task of technical means of diagnosis and monitoring is to analyze the state of precisely the floor technological equipment of railway automation with fixing subcritical (pre-failure) conditions.

The number of outdoor technological facilities and their features are determined directly based on track development of the station and permissible technological operations at it. For example, Pic. 1 shows a schematic plan of an arbitrary intermediate station in a single-line version (such stations are widespread on railways) [13, p. 279].



Pic. 1. Schematic plan of an intermediate station [13, p. 279].

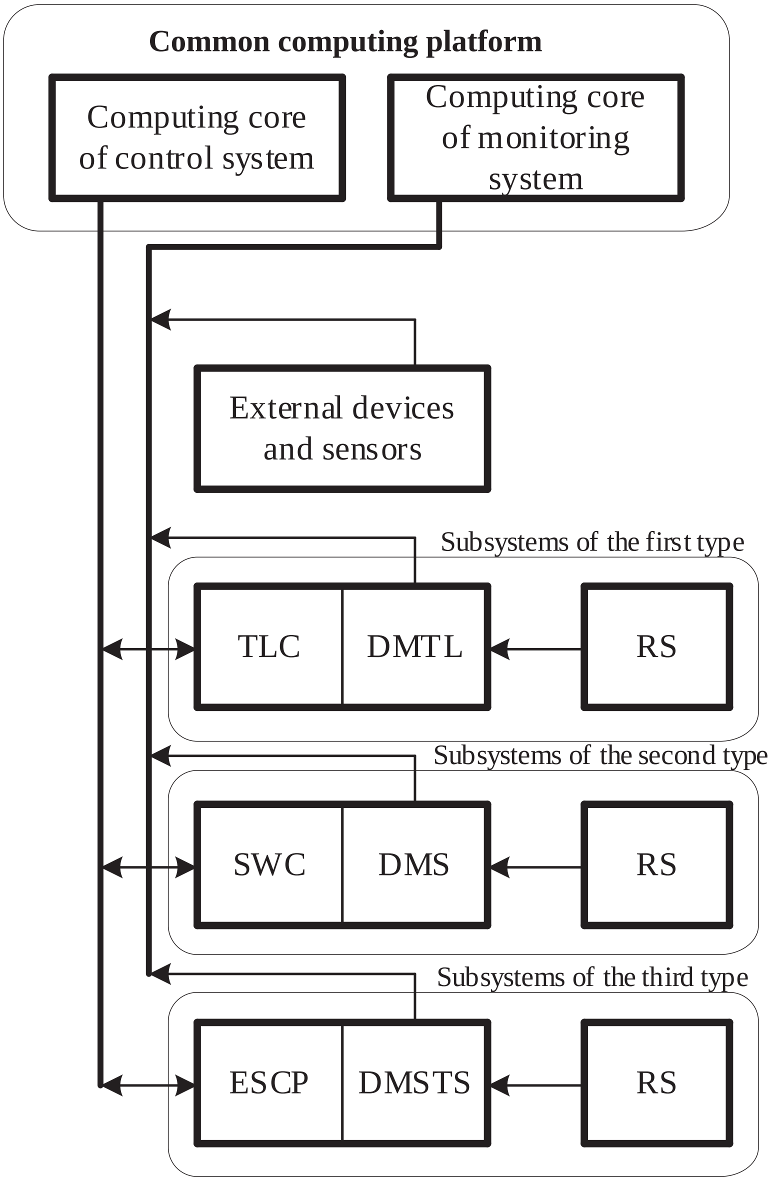
At the station in question, 18 track circuits (8 branched and 10 unbranched) are used to position the moving units. To move trains from one track to another, 15 turnouts equipped with turnout electric drives were stacked at the station. Movement is regulated by 14 train and 5 shunting traffic lights. These are the main objects of monitoring.

Outdoor technological equipment of railway automation in modern monitoring systems is diagnosed by indirect signs by the state of control devices located at the centralization station [8, p. 43]. Often, due to the peculiarities of cable system of railway automation, the set of diagnostic parameters is very limited and allows to evaluate only the general state of a group of devices, while it is extremely difficult to identify without expert judgment the state of a particular object or to attribute the obtained measured value to an object. For example, the control devices of the motors of switch electric drives are most often mounted on feeding devices and measurements are taken in the circuits of switches when they are subsequently moved at each of the necks. If part of switches can be moved in parallel, then the measurements could not be unambiguously associated only with a specific railway switch. In this case, phase currents and interphase voltages are measured in the circuits. In addition to this information the condition of the railway switch is judged by discrete data of its position and the state of control facilities. It should be noted that on the EU railways development of technical means follows the path of decentralization of diagnostic tools and their location in close proximity to the object of diagnosis and through expanding their functionality [14; 15]. For traffic lights, the current in the enable circuit of the permitting indication and discrete states are measured (often, only the permitted indication, and not a specific lens kit). For track circuits discrete states (occupied/free, closed/not closed in the route, activation of cancellation or artificial disconnection mode), as well as a number of voltages: voltages on power supplies and track elements (relays) with phase-sensitive rail circuits; voltage at the outputs of generators, track receivers and track elements (relays) with tonal rail circuits. In addition, duration of code messages of the automatic locomotive signalling coding system is used as diagnostic parameters. The information on the state of the power supply system at the station, as well as on the state of insulation resistance of the cable system is added to the data obtained.

As practice shows, the presented set of data is not enough for an accurate diagnosis and subsequent prognosis. Let's consider an approach that expands completeness and depth of technical diagnosis, applicable in development of new interlocking systems.

Integration of diagnostic functions into object controllers

Control systems can be implemented according to various ideologies [16]. Currently, a single computing complex located at the centralization post or in a portable module are used. This computing complex is implemented using traditional relay technology, as well as using microelectronic and microprocessor components. To control peripheral objects in station automation systems, interface relays or object controllers are used (a more modern version). By geographic location relative to the computing complex, object controllers can be centralized or decentralized. With centralized location, object controllers are located in close proximity to the computer complex and communicate with peripheral control and control objects using a cable. With a decentralized location, object controllers can be placed in close proximity to peripheral



Designations

TLC – traffic lights controller;
SWC – switch controller
ESCP – equipment of sensors of control of moving units position;
DMTL – diagnostic module of traffic lights;
DMS – diagnostic module of switches;
DMSTS – diagnostic module of a switch-track section;
RS – remote sensors.

Note. All connections can be wired or wireless.

Pic. 2. Structure of organization of the monitoring system (author's design).

objects: in travel boxes and drawers, in traffic lights boxes or even in traffic lights heads. In this case, control orders and control information are also transmitted via the cable network to the object controllers. Power supply can be organized under both local and centralized mode. The implementation method depends on the chosen ideology and the specifics of the station itself. It is worth mentioning a promising, but not yet implemented cableless control method, when all object controllers are located in close proximity to the objects, are supplied with energy from local sources (both traditional and alternative), and data are transmitted to a single control complex via wireless communication [17, p. 23].

It is proposed that each object controller be equipped with an easily removable measuring module that provides diagnostic data that allow the most complete analysis of the technical condition of controlled objects. Data should be transmitted via dedicated diagnostic transmission channels – either cable (if there is a cable network) or wireless.

For the most effective monitoring process of controlled objects, the following parameters are required. For object controllers for control of switch motors, measurement of interfacial voltages, phase currents, insulation resistance of the cable relative to the ground (when using cable system) is required. For object controllers of traffic lights – voltage supply of the lamps of the lights of traffic lights (power supply of LED lamps) and currents in the power supply circuits, insulation resistance of the cable relative to the ground (when using cable system) should be controlled. If the traffic light controller is installed in the traffic light box or in the traffic light head, then for monitoring the geometric position of the mast (if any), the diagnostic device is equipped with a deflection angle monitoring sensor which is an inclinometer [18, p. 177]. The composition of data from the equipment of sensors for monitoring the position of mobile units is determined by the type of these sensors. For example, when using modern audio-frequency track circuits, control and monitoring are carried out using a generator, a filter, a receiver and relay (in the future it can be replaced by a microelectronic device or, in general, excluded from work). It is worth noting that the function of the rail circuit is precisely control of the position of rolling stock, and not control; however, control is carried out from the generator by supplying current of a certain frequency and receiving it by the track receiver from the receiving side. Thus, currents and voltages at the outputs of generators, track receivers, filters and relays, as well as insulation resistance of the cable relative to the ground (when using cable system) will be required.

Additionally, for each controlled object, an analysis of such parameters as vibrational influences on the object and climatic operating conditions is required. For this purpose, a remote device based on accelerometers or an integrated sensor in the diagnostic module can be used, as well as each measuring module can be equipped with a temperature sensor. Either a weather station is installed at the monitoring object. Each object controller must also transmit data to its monitoring system about its status and the state of the power supply system.

Embedded diagnostic modules can also serve as primary data processing device on the state of objects of adjacent facilities [19, p. 65]. For example, the most important task is to control the mechanical and geometric parameters of the rail track and the railway switches themselves. To monitor them, remote sensors can be used located both on the internal elements of the devices and on external objects with a wired or a wireless interface (an example is the well-known solution for monitoring the geometry of the switch turnout [20]).

It should be added that the measuring module itself should be a means of obtaining many diagnostic parameters from one group of interconnected objects, some of which should be processed directly «on the spot», and some should be transmitted to the monitoring server.

The architecture of the technical diagnosis and monitoring system has the form shown in Pic. 2.

It should be noted that we are talking about monitoring railway automation equipment. However, to obtain a digital picture of the state of objects at the station, monitoring of geometric and physical parameters of such objects as the track superstructure, catenary, and artificial structures is required. In addition, the parameters of moving units can be taken into account and weighting the train on the go per load on each axis of each wagon's bogie can be used. Thus, the global development path of technical diagnostic and monitoring systems consists in integrating many functions for measuring the operating parameters of not only railway automation facilities, but also railway infrastructure facilities.

Conclusion. The use of integrated technical diagnostics and monitoring tools allows to significantly expand the capabilities in the analysis of diagnostic data from railway automation facilities and make the transition to automation of forecasting and identifying precautionary conditions. It should be noted that, at the same time, the diagnostic devices for checking procedures themselves can be easily dismantled and replaced due to standardization and modularity of execution, while the diagnostic circuits are separate. This makes it possible to organize separate (independent of control systems) systems of technical diagnostics and monitoring, including the use of universal platforms for analysis of big data flows. Many diagnostic parameters can be expanded and supplemented to obtain a digital picture of the state of the station infrastructure facilities and record these data during operation. The data itself from a single platform can be transferred to automated workstations (stationary or mobile) of specialized technical personnel according to their competencies.

The implementation of the approach described in the article allows to move to a new stage in technical diagnosis and monitoring and to make a qualitative transition to achieving three main goals: obtaining an accurate diagnosis, forecasting and assessing the residual life of monitored objects.

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