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Development of structural schemes for collecting monitoring and diagnostic data of signaling points of the railway run based on programmable logic controllers

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Abstract: The article talks about the problems and shortcomings of collecting various diagnostic data at signal points of existing dispatching control systems of railway automation. As a solution to these problems, structural schemes for collecting analog and discrete diagnostic data have been developed based on a programmable logic controller. On the basis of the developed structural schemes, tests were conducted on measuring voltages in two types of analog signals, and the results of the dependence of the mean square deviation on the request time in determining the effective value of the voltage were given..

Keywords: : Programmable logic controller, control, technical diagnostics, monitoring, analog signals, discrete signals, measurement, query time, measurement.

Introduction

On the railways of the Republic of Uzbekistan, automation is controlled by a dispatch control system introduced in the 60-70s of the last century [1-2]. The controlled information mainly includes the entrance and exit traffic light signs at the station, the state of receiving and sending roads, the condition of the block section on the stages, and the crossing traffic light signs. By the end of the 20th century, the emergence and rapid development of microprocessor technologies did not bypass these systems. Based on these technologies, new generations of technical diagnostics and monitoring systems have begun to be created. These include the APKDK, ADKSSB and ASDK systems [3-4]. Such systems allow, to a certain extent, to reflect the technical condition of diagnosed objects, predict their next technical condition, systematize the actions of technical personnel to identify and prevent malfunctions, accidents, etc. [5]. Therefore, monitoring systems are designed to increase the reliability and fault tolerance of train traffic control devices and systems, including, to a certain extent, indirectly affecting the safety of train traffic and in some cases making it possible to identify critical deviations in the operating parameters of diagnostic objects [6].

The above-mentioned systems have a number of disadvantages, for example, due to the narrow scope of the technical diagnosis of the dispatch control system, it cannot cover some

parameters of the diagnosed object. In addition, the high consumption of resources and energy is the reason for its wear and tear. Relatively newer technical diagnostic and monitoring systems are distinguished by their high cost and the high cost of technical support services due to the fact that they are a monopoly in the market of such systems. This means that the restoration of the failed part of the system is carried out only by a special employee of the manufacturing company, or any defective part is not available in any company other than this manufacturer. This leads to dependence on the products of these monopoly firms and economic losses. To prevent this, it is possible to use microcontrollers and electronic components in devices of such systems. As a result, the developed device can become several times cheaper and expand its functionality. But when using a microcontroller, there is a problem of not being able to expand the input and output modules using discrete and analog signals. In this case, programmable logic controllers are the best solution.

Taking into account the listed shortcomings, it is desirable (recommended) to develop modern technical diagnostics and monitoring systems on the basis of programmable logic controllers PLC that meet world standards and have the possibility of expanding the input and output modules widely used in automation systems in the production industry. Despite the fact that PLCs are manufactured by different foreign companies under different names and modifications, the protocols for writing programs and data exchange for them are based on the principle of generally recognized standards. This means their universality, that is, the program logic written for the controller of one company is also suitable for the controller of another company[7-9].

There are many PLC manufacturers in the world market, among which Siemens, Schneider Electric, ABB, Fastwel, "Oven", "Vympel", and Delta Electronics are the most popular. Taking into account their technical and economic indicators, we will consider the task set on the example of Delta Electronics PLCs [9]. Delta Electronics has a variety of PLCs and extended I/O modules designed for automation of production processes, which are mounted on a DIN rail for convenient placement of modules during the construction of automated systems (Fig. 1). Functional modules of the firm are classified as follows[10]:

node controllers;

discrete information input/output modules;

analog information input/output modules;

power modules, power multipliers;

network interface modules;

temperature measurement modules.

Based on the Delta Electronics modules, it is necessary to select the modules that are compatible with the parameters in the implementation of the assigned task. In addition, based on our local climatic conditions, it is necessary to pay special attention to their technical indicators. Below we will consider the products of Delta Electronics modules designed to perform various tasks. Based on these modules, we provide examples of entering diagnostic and monitoring data and connecting peregon signal point objects to control points.
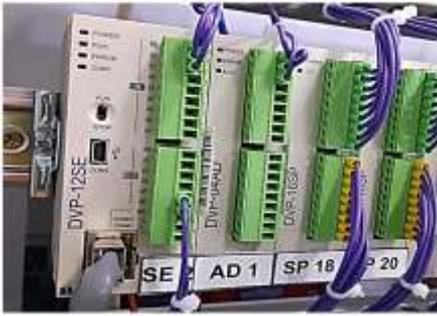
Figure 1. Serial arrangement of Delta Electronics PLC modules on the rail

Node controllers (Fig. 2) input digitized (transformed into a standard form) data from extended modules, process them, execute commands to the software according to logic, exchange data with other network modules, provide final data intended for release to the user. Depending on its modifications, each network controller has a certain amount of temporary and permanent memory. All modules work on the basis of a real-time operating system.

Figure 2. Node controllers from Delta Electronics

Information exchange between node controllers and between users can be carried out according to the manufacturer's ready-made solutions, depending on the modification of the used node controllers. In this case, the distance of their information exchange depends on the type of physical communication channel used as follows:

CAN - up to 1000 m;

RS-422 - up to 1200 m;

RS-485 - up to 1200 m;

Ethernet - up to 100 m.

In the process of technical diagnosis of automation objects, it is required to record various parametric properties and values connected to their control points. Basically, such values have two forms, they are divided into discrete and analog types. For this task, in addition to the modules listed above, Delta Electronics has a variety of input-output modules designed for receiving and outputting discrete and analog data. For example, advanced modules such as DVP-16SM for 16 discrete data inputs, DVP-16SP for 8 discrete data inputs and 8 discrete outputs, and DVP-XXAD for 4 analog data inputs are used (Figure 3). A common automated system is created by serially connecting various extended modules that are compatible with these PLCs based on the task of automation (Fig. 1).

Figure 3. Advanced I/O modules

Delta Electronics' discrete input modules are capable of accepting and decoding DC voltages from 0 to 30 volts. To input discrete data from monitoring and diagnostic devices, empty contacts of relays, contacts of disconnectors, push buttons and the like can be used as sensors. For example, Figure 4 shows the structural diagram of the connection of sensors of the open contact type to the discrete input module DVP-16SM. The discrete inputs of this module are supplied with +24 volt voltage from the power supply units through the sensors.
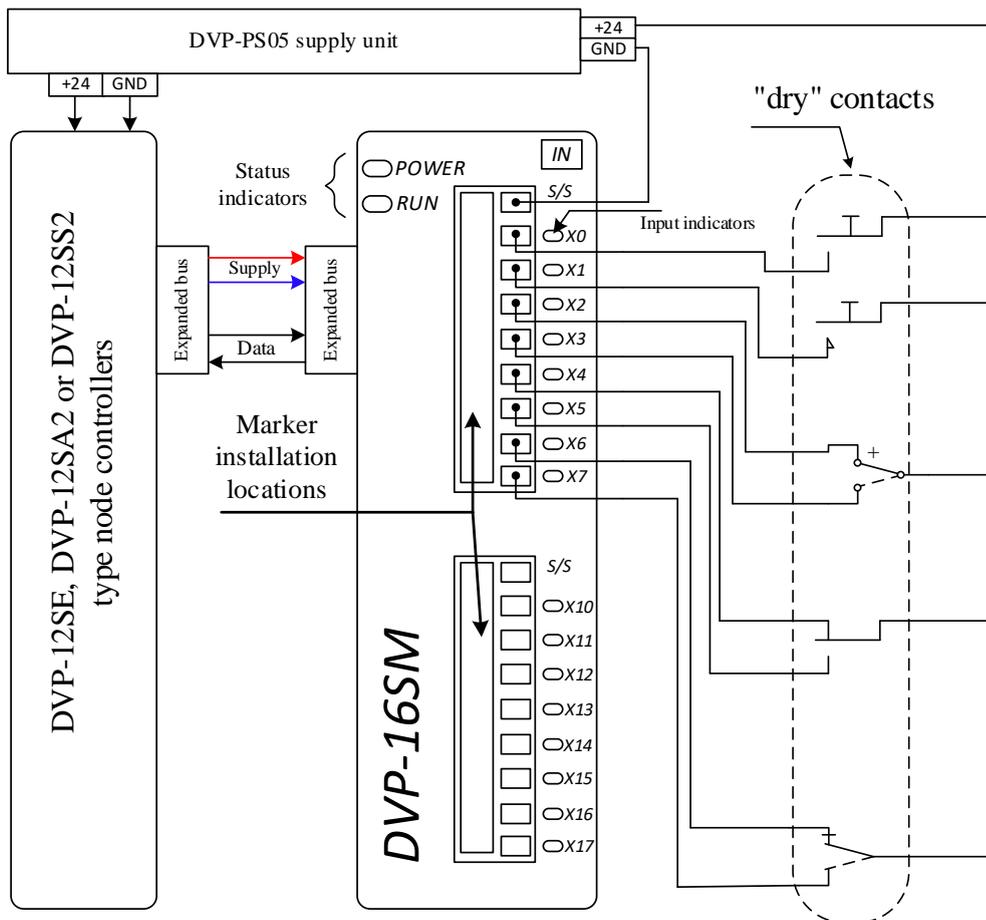

Figure 4. Structural scheme of connecting the DVP-16SM type discrete signal collection module to the "dry" contacts of automation devices

Delta Electronics DVP-XXAD modules are used to input parameters in analog values. In particular, the DVP04AD-S type module from DVP04AD-S is an analog input module capable of operating in potential or current modes. These products are expansion modules for DVP-S(SA/SX/SC/SV) series node controllers, which can be connected directly or remotely via RS-485 and Modbus communication protocol, which can be used as data acquisition modules. Both in potential and current mode, the modules require a separate connection to the power supply. The

input signal range in potential mode is $10 \div +10$ V DC (with a minimum step of 1.25 mV), in current mode - $20 \div +20$ mA (with a minimum step of 5 mA). The module uses analog-to-digital converters with a capacity of up to 14 bits in potential mode and 13 bits in current mode [11-12]. Based on these potential and current ranges of the input signal of the DVP04AD-S type module, it is possible to measure certain parameter ranges by connecting directly to the module itself, without the use of special current sensors. It should be noted that railway automation uses wider ranges of voltages and currents than the above measurement ranges, and therefore other specific technical diagnostic problems arise. These are tasks such as measuring voltages above the module's measurement ranges and determining the cable insulation resistance [5;6;13]. This requires special sensors that measure the voltage (current) between the device and the module. In such cases, it is recommended to use current and voltage sensors to measure current and voltage using the analog input modules listed above (Figure 5).

Figure 5. Standard current and voltage sensors for PLC analog signal input modules

Many manufacturers produce these sensors with standard 0-20 mA or 4-20 mA DC output signals for input to analog PLC modules. It is also necessary to monitor several voltages at the auto-lock alarm point, which operate in ranges greater than the measurement ranges of the DVP04AD-S module, which must be measured using the current sensors specified above. To measure and monitor the analog signals of signal point devices, several test points have been identified in existing electrical circuits. It is also proposed to exclude some devices from the scheme.
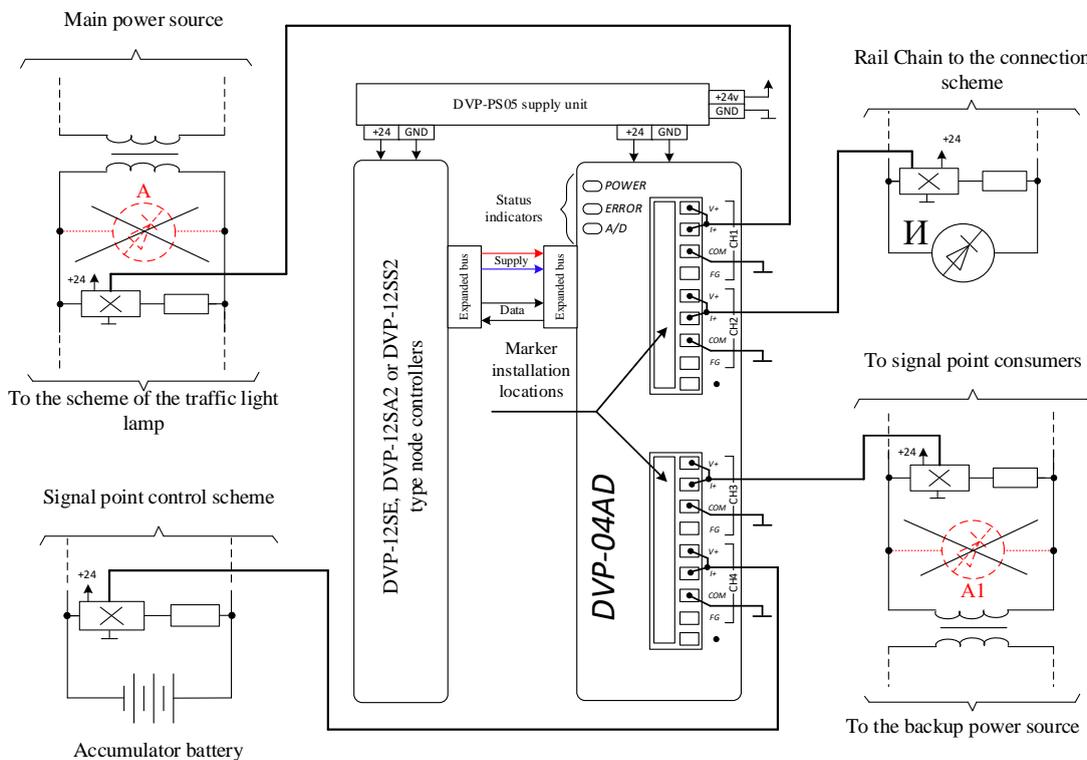
Figure 6. Structural scheme of connecting the DVP-04AD module to the current (voltage) sensors of automation devices

The structural scheme of connecting the DVP04AD-S module to the control points identified in the current circuits of the signal point through current and voltage sensors is shown in Fig. 6. In the picture, it is proposed to remove the emergency relay A connected to the main power source and connect a resistor and a current sensor in parallel to this circuit instead. In the same way, it is planned to remove the additional emergency relay A1, which connects to the backup supply source. Resistor and current sensors are connected in parallel to the circuits of the accumulator battery and I track relay.

Based on the developed structural schemes, tests were conducted on measuring alternating voltages of 110 and 220 volts with a frequency of 25 and 50 hertz as analog signals. In the conditions of railway automation and telemechanics, the mean square deviation values of measuring devices should not exceed 2% [14]. If we take the amount of voltage as 110 volts, the maximum average square deviation from $\sigma_{max} \leq 2{,}2$ volts, if we take it as 220 volts, then the maximum average square deviation should not exceed $\sigma_{max} \leq 4.4$ volts. During the experiments, a curve $\sigma_1(t)$ was obtained, which reflects the variation of the mean square deviation of the voltage measurement $\sigma_{\Delta x}$ in the ideal form of the signal depending on the request time t_0. In the presence of harmonic distortions, the curve $\sigma_2(t)$ was also obtained, which reflects the change of the average square deviation of the voltage measurement $\sigma_{\Delta x}$ depending on the request time t_0. The estimation of the required request period t_0 is carried out in the limits from σ_0 to σ_{max}.

Figure 7 presents the results of experiments in the form of dependences of the standard deviation on the sampling times of analog signals when determining the effective values of the AC supply voltage using the ADC of the DVP20SX2 programmable logic controller, used on an industrial scale. The monitored analog signal was measured using the ADC module at various request times from 0.3 ms to 6 ms.
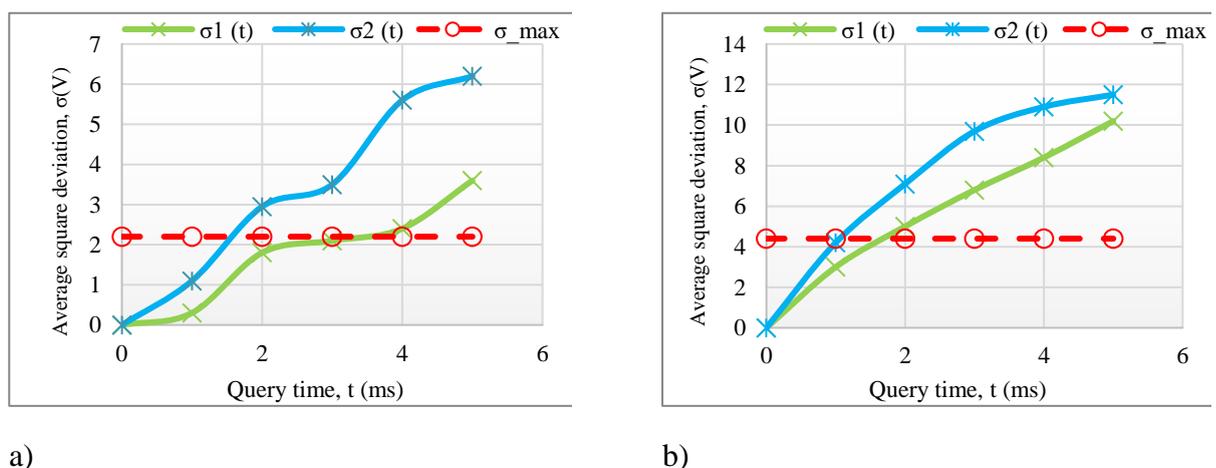

a)   b)

Figure 7. Dependence of the avarage square deviation on the sampling time when determining the effective value of the monitored analog signal:

 a) analog signal with a voltage of 110 V and a frequency of 25 Hz

b) analog signal with a voltage of 220 V and a frequency of 50 Hz

If we analyze the curves $\sigma_1(t)$ and $\sigma_2(t)$, obtained from the results of an experiment conducted using the example of the DVP20SX2 industrial controller, we can come to the following conclusions:

the results obtained for an analog signal with a voltage of 110V and a frequency of 25Hz do not exceed the maximum permissible standard deviation for both types of analog signal when requesting an ADC t_0=1.5 ms.

the results obtained for an analog signal with a voltage of 220 V and a frequency of 50 Hz do not exceed the maximum permissible standard deviation for both types of analog signal when requesting an ADC t_0=1 ms.

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