Improvement of Control Units for Shunting Traffic Lights in the Alignment of Railway Automation and Telemechanics and Their Economic Efficiency

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**Abstract.** Today, one of the urgent problems in all developing countries, not only in railway transport, but also in other sectors of the economy in general, is the introduction of energy and resource-saving technologies and the identification of ways to effectively use them. Including in railway transport, there are outdated and high-power automation and telemechanics systems [1, 2]. This, of course, has a sufficiently negative impact on the sustainable development of the industry. This article analyzes the development of NM2P and NM2AP electromagnetic blocks, which control shunting traffic lights located in two bays in the “Blocked Route Relay Centralization” system, one of the automations and telemechanics centralization systems used at railway stations, based on energy-efficient microprocessor industrial controllers. That is, it is envisaged to develop algorithms for the electrical circuits of traditional electromagnetic relay blocks, create software, and then replace real electrical circuits with logical operations. Also, their economic efficiency is presented on the basis of specific calculations [5].

**Keywords:** railway transport, electromagnetic relays, electromagnetic blocks, modeling, logical functions, programmable logic controllers

# Introduction

In the BMRM system, the NM2P and NM2AP control blocks, responsible for operating two combined shunting signals, are assembled using five and six KDR-type electromagnetic relays, respectively, mounted on a single base. KDR-type relays, classified as devices with second-class reliability based on their technical specifications, are associated with a range of operational issues. For instance, contact sticking, unreliable connection between contacts, the need for constant maintenance, high energy consumption, etc. [4]. To solve such problematic situations, it is important to introduce modern technologies in the industry. In this regard, programmable logic controllers (hereinafter referred to as PLCs) provide us with a high level of reliability and flexibility, allowing us to control the facility with minimal energy consumption. In this regard, the purpose of this article is to consider the main characteristics, operating principles and experience of application in the industry of industrial controllers of the GLC196R type [6].

**METHODOLOGY**

GLC196R industrial controllers are designed taking into account the requirements of modern automation and control systems, the device is equipped with a powerful control processor, which provides high data processing speed and execution of complex algorithms. GLC196R supports connection to analog and digital input and output modules.

Communication interfaces: PLC supports various communication protocols, including Modbus, Ethernet, Profibus, etc. This ensures easy integration with other devices and systems.

PLC is programmed using the Ladder programming language, the ladder syntax is convenient for replacing logic circuits implemented on the basis of relays. The programming platform provides a logical visual interface, which facilitates not only programming and commissioning tasks, but also quick troubleshooting of equipment connected to the PLC.

GLC-196R operates on the basis of a data processing cycle, which includes the following stages:

• Data reading: reads data from all input devices.

• Information processing: based on the received data, the controller performs logical operations and algorithms described in the program code.

• Device control: used to generate commands to perform actions such as data processing results, signal transmission or stopping at the outputs, parameter adjustment, etc.

In addition to its technical capabilities, the GLC196R offers several operational superiorities:

Advantages:

1. Superior reliability and resistance to external influences.

2. Ability to integrate into higher-level control systems.

3. Ability to reprogram and add new functions.

4. Small size and light weight.

5. No need for regular maintenance.

No need for regular maintenance.Examining the housing for signs of mechanical damage, such as deformation, burns, or surface wear.

* Verifying secure mounting of the controller at the installation site.
* Inspecting connected cabling for tightness, mechanical wear, and absence of stress or pinching.
* Ensuring terminal connections remain secure.
* Confirming correct grounding, which is critical for operational safety.
* Checking environmental conditions (temperature and humidity) comply with industry standards, typically within 0°C to 55°C.
* Assessing the condition and fit of I/O modules.
* Observing LED status indicators (e.g., Power, Fault, Comm) to ensure normal operation (typically indicated by steady or blinking green lights).
* Evaluating the installation environment for excessive vibration, dust, or chemical exposure, which may

It is also worth noting that PLCs are the basis of industrial automation systems, and their average service life is 10-15 years. During this period, technological innovations, changing needs, and safety requirements make it necessary to update the PLC.

1. New technologies are created — for example, more powerful and faster processors, energy-efficient components, or powerful security systems.

2. Software support ends — over time, new operating systems or updates are no longer released for older devices.

3. Compatibility issues arise — older devices experience limitations when working with new devices.

4. User needs change — for example, working with large amounts of data, adding additional features, providing connectivity to higher levels.

A comparison of the general requirements for devices is presented in Table 1.

From the data, it became clear that industrial controllers have a clear advantage in comparisons in general aspects, next we will compare the specific technical characteristics, that is, the power consumption of the devices.

**TABLE 1.** Comparison table of PLC and Electromagnetic relays according to general requirements

|  |  |  |  |
| --- | --- | --- | --- |
| № | **Parameters** | **PLC** | **Electromagnetic Relay** |
| 1 | Reliability | High | Mechanical wear and tear and failures |
| 2 | Flexibility | High and possibility of making changes | Requires reconnecting |
| 3 | Changes in logic | Fast and easy | Replacing/adding components |
| 4 | Life cycles | 10–15 years | 10–15 years |
| 5 | Service | Minimal | Regular (checking contacts, etc.) |

**RESULTS AND DISCUSSION**

The traditional dialing group block NM2P includes 5 electromagnetic relays. Their technical and electrical characteristics are presented in Table 2 below [3].

**TABLE 2.** Technical and electrical characteristics of electromagnetic relays

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Relay type | Name | Quantity  (pieces) | Voltage(V) | Coil resistance (Ω) | Current (mA) |
| KDR1-280 | K | 1 | 24 | 280 | 86 |
| KDR1-200 | KN | 1 | 24 | 200 | 120 |
| KDR1M-280 | MP | 1 | 24 | 280 | 86 |
| KDR1M-435 | VP | 1 | 24 | 435 | 55 |
| KDR1M-435 | VKM | 1 | 24 | 435 | 55 |

Based on the data presented in Table 2 above, the electricity consumption per hour can be calculated based on the following expression (1).

Q=A=UIt=I2Rt (1)

According to expression (1), the requirement of relay K is as follows (2):

QK=24\*86\*10-3\*1=2,06 \*10-3 kWh (2)

The KN relay consumption is as follows (3):

QKN=24\*120\*10-3\*1=2,88 \*10-3 kWh (3)

The MP relay requirement is as follows (4):

QMP=24\*86\*10-3\*1=2,06 \*10-3 kWh (4)

The VP relay requirement is as follows (5):

QVP=24\*55\*10-3\*1=1,32 \*10-3 kWh (5)

The VKM relay requirement is as follows (6):

QVKM=24\*55\*10-3\*1= 1,32\*10-3 kWh (6)

In general, the power consumption of the complete unit is as follows (7):

Q um = QK + QKN + QMP + QVP + QVKM = 2,06+2,88+2,06+1,32+1,32=9,64\*10-3 kWh (7)

The NM2AP conventional dialing group block includes 6 electromagnetic relays. Their technical and electrical characteristics are presented in Table 3 below [3].

**TABLE 3.** Technical and electrical characteristics of electromagnetic relays

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Relay type | Name | Quantity  (pieces) | Voltage(V) | Coil resistance (Ω) | Current (mA) |
| KDR1M-3.8 | АKN | 1 | 1.7 | 3.8 | 448 |
| KDR1-280 | K | 1 | 24 | 280 | 86 |
| KDR1-200 | KN | 1 | 24 | 200 | 120 |
| KDR1M-280 | MP | 1 | 24 | 280 | 86 |
| KDR1M-435 | VP | 1 | 24 | 435 | 55 |
| KDR1M-435 | VKM | 1 | 24 | 435 | 55 |

Based on the data in Table 2 above, the electrical energy consumption per hour can be calculated according to Expression 1 below. In this case, the consumption of the AKN relay based on Expression 1 is as follows (8)

QAKN=1.7\*448\*10-3\*1=0,761 \*10-3 kWh (8)

The K relay requirement is as follows:

QK=24\*86\*10-3\*1=2,06 \*10-3 kWh (9)

The KN relay is used as follows:

QKN=24\*120\*10-3\*1=2,88 \*10-3 kWh (10)

The MP relay is designed as follows:

QMP=24\*86\*10-3\*1=2,06 \*10-3 kWh (11)

The VP relay requirement is as follows:

QVP=24\*55\*10-3\*1=1,32 \*10-3 kWh (12)

The VKM relay is used as follows:

QVKM=24\*55\*10-3\*1= 1,32 \*10-3 kWh (13)

Total electricity consumption:

Q um = QAKN + QK + QKN + QMP + QVP + QVKM = 0.761+2.06+2.88+2.06+1.32+ 1.32=10.401\*10-3 kWh (14)

The NM2P-M block, developed based on industrial controllers, consists of one control controller GLC-196R and two input and output modules GXM-88RA, which, according to their technical characteristics. Energy consumption is presented in table 4.

**TABLE 4.** Power consumption of PLC modules used for the NM2P-M unit

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Quantity | Voltage(V) | Electricity consumption (kWh) |
| GLC-196R | 1 | 24 | 3\*10-3 |
| GXM-88RA | 1 | 24 | 1\*10-3 |
| GXM-88RA | 1 | 24 | 1\*10-3 |
| Total |  |  | 3+1+1=5\*10-3 |

The NM2AP-M unit, designed based on industrial controllers, consists of one GLC-196R controller and three GXM-88RA input and output modules. Energy consumption is presented in table 5.

**TABLE 5.** Power consumption of PLC modules used for the NM2AP-M unit

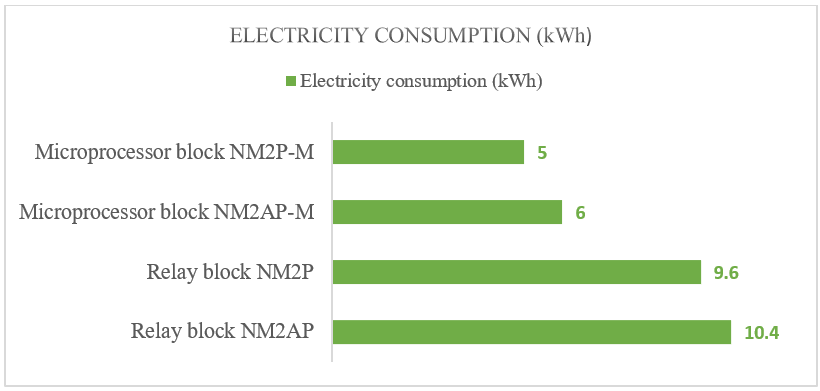
|  |  |  |  |
| --- | --- | --- | --- |
| Name | Quantity | Voltage(V) | Electricity consumption (kWh) |
| GLC-196R | 1 | 24 | 3\*10-3 |
| GXM-88RA | 1 | 24 | 1\*10-3 |
| GXM-88RA | 1 | 24 | 1\*10-3 |
| GXM-88RA | 1 | 24 | 1\*10-3 |
| Total |  |  | 3+1+1+1=6\*10-3 |

The differences in energy consumption between the developed microprocessor blocks and relay blocks are clearly visible in Table 6.

**TABLE 6.** The differences in power consumption between the developed microprocessor blocks and relay blocks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Name | Relay block NM2AP | Relay block NM2P | Microprocessor block  NM2AP-M | Microprocessor block  NM2P-M |
| Electricity consumption (kWh) | 10.403\*  10-3kWh | 9.642\*  10-3Wh | 6\*10-3kWh | 5\*10-3kWh |

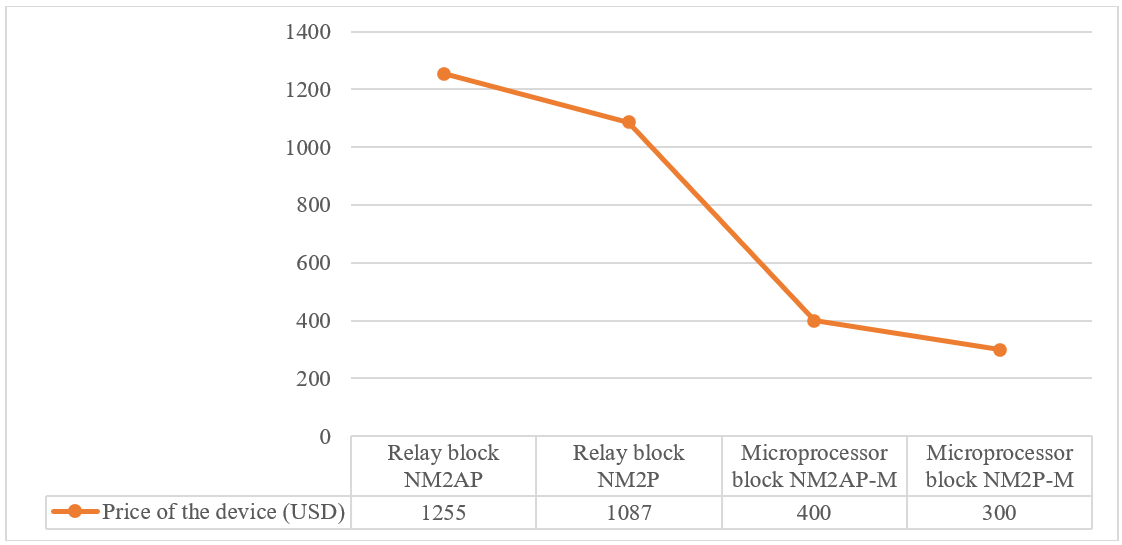
Based on the data presented in Table 6, the following electricity consumption can be represented in the form of a diagram Figure 1.



**FIGURE 1.** Electricity consumption diagram

Currently, the significant increase in the cost of energy resources on a global scale is creating problematic situations for many industrial enterprises. According to the diagram, the halving of electricity consumption over time will certainly be a significant impetus for the sustainable development of the industry.

Next, we will compare the price of the device Figure 2.

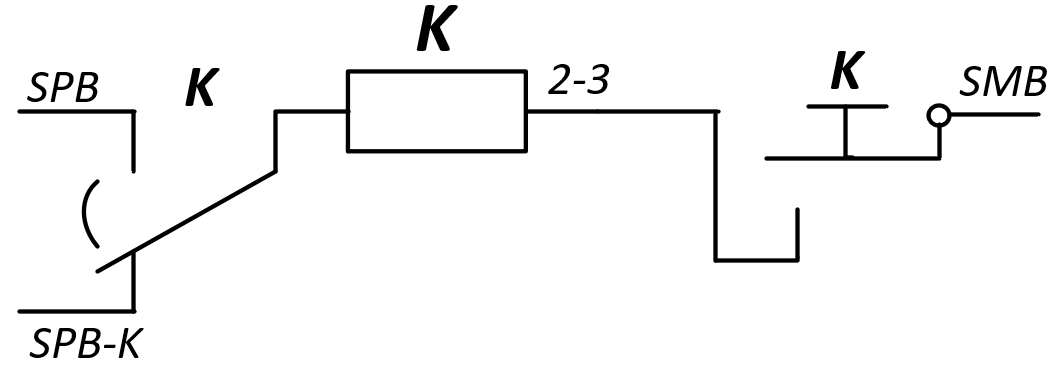


**FIGURE 2.** Price of the device (USD)

The novelty of the research results is that algorithms and mathematical models for all elementary circuits have been developed for the development of a microprocessor block. Let's consider this on the example of a small chain of blocks. For instance, if we analyze the electrical circuit of relay K (Figure 3), expressions (1) and (2) must be fulfilled for the relay to operate.

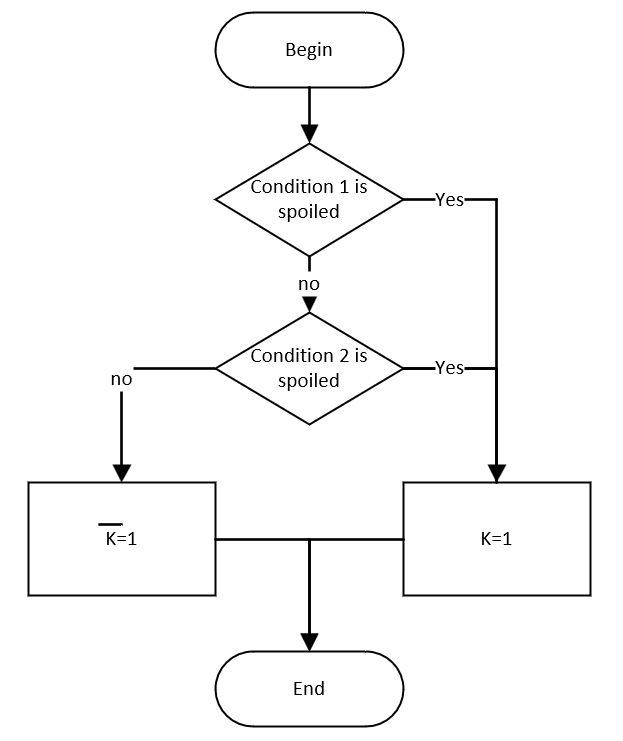
[SPB-K→K↓→2-3→SMB] [K=1] (15)

[SPB→K↑→2-3→SMB] [K=1] (16)



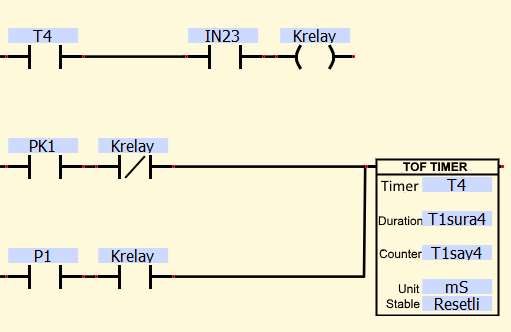
**Figure 3.** K relay electrical circuit

According to the above conditions, the algorithm for the operation of the k relay was developed:



**Figure 4.** Algorithm of operation of relay K

Of course, the software can be developed based on the presented algorithm as follows (Figure 5).



**FIGURE 5.** Ladder programming language representation of software

Above, the elementary chain-based replacement scheme was considered, and this is achieved by implementing blocks in rung-like chains.

**CONCLUSION**

The economic efficiency of implementing the NM2P-M and NM2AP-M microprocessor-based control blocks is achieved through several key factors:

* Elimination of labor costs associated with the repair and routine maintenance of traditional relay-based control units;
* Reduction in the consumption of material resources, spare parts, and components typically required for periodic servicing;
* Lower energy consumption, even during the structural modernization process involving the integration of microprocessor-based blocks;
* Enhanced operational reliability, with a significant reduction or complete elimination of the human factor during operation, leading to minimized equipment malfunctions and reduced train delays;
* Significant foreign exchange savings through the localization of production within the territory of the Republic of Uzbekistan.

Beyond economic advantages, the domestic production of the NM2P-M and NM2AP-M blocks contributes to the fulfillment of national development strategies. These include state programs on localization, the reduction of import dependency in strategic industrial sectors, the promotion of energy-efficient technologies, modernization of outdated equipment, and the widespread adoption of automation and innovation across railway transport systems.

The reduction in failures of automation and telemechanics equipment as a result of deploying modernized systems has a positive systemic effect on the railway network. This includes increased average train speeds, enhanced throughput capacity of rail segments, lower operating costs, reduced unit cost metrics, improved profitability of operational activities, and a higher overall level of transport safety.

Specifically, the NM2P-M microprocessor unit, unlike its electromechanical relay-based counterpart, does not require periodic inspections or ongoing maintenance by electromechanical personnel, thereby eliminating recurring labor expenditures and simplifying operational workflows.

The GLC-196R PLC is a reliable tool for automating and controlling various processes. Its integration with other systems, ease of programming and modular architecture make it a reliable choice for modern production. Like any technical solution, the use of the GLC-196R requires a careful approach to system design and configuration, but its advantages make it an indispensable part of the automation industry. It is worth noting that the article analyzed the data in the process of comparing the general characteristics of the devices, their power consumption and their cost. The results of the analysis showed that the use of modern technologies in the system has a clear advantage.

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