Application of Microprocessor-Based Digital Signaling and Blocking Systems in Railway Transport Together with Neural Networks

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***Abstract*—There is a growing demand for speeding on railways and various programs are being implemented. In this case, the structural defects in the relay systems became a reality, and it was not possible to take the necessary measures to eliminate these shortcomings at the design stage of the control system. Modern experience shows that there are a number of shortcomings in relay, mechanical and relay processor systems. In this paper, the use of recommended methods is explained, stating the functional safety requirements used in railway signaling systems. In particular, the use of several methods in defining the software development process and software hardware architecture was discussed. The article presents the advantages of the microprocessor system over relays, relay-block and relay-processor systems and discusses its use in conjunction with a neural network. The frequency of occurrence of related scenarios was calculated in the reliability analysis using a general analytical model to compare the architectures of different blocking circuits in terms of security and usability. This document presents the results related to the safety of the machines and reflects the analysis method itself to support the selection of blocking architecture systems. It examines the analysis and selection of security methods for microprocessors and programmable logic controllers. The article considers the main indicators of the security functions of the system, makes suggestions on the technological processes of production in order to ensure safety.**

Keywords—microprocessor centralization, railway signaling and blocking system, microprocessor, security architecture, integrated security level, relay, digital system.

I. INTRODUCTION

At present, it is impossible to imagine any field of railway transport without microprocessor systems. The main purpose of the railway automation and telemechanics system is to ensure the safety of trains, as failures and malfunctions (failures) in stations, road junctions, level crossings, bridges and tunnels, alarm systems installed in apartments can lead to numerous casualties.

The choice of hardware architecture in the design of interlocking circuits for signal exchange in machine protection systems in microprocessor centralization affects machine safety and availability. In an emergency, reliable stopping of the system elements (keeping the machine safe) is a special requirement. On the other hand, the limitations in terms of machine availability are different for different devices. To some extent, it is possible to allow incorrect parking, which reduces the accessibility of the machine, in places where it does not cause excessive wear of the equipment.

The analysis of the initial statistics allows to determine the general trend and regularities of change in the parameters of the devices of the centralization systems in operation. All calculations were carried out with a tolerance of ± 5, as allowed. Taking into account the operating conditions, traffic volume and climatic effects, the technical condition and reliability of the devices of railway automation and telemechanics systems are assessed by a complex change in these effects. Thus, the operation of field equipment, such as relay cabinets, centralized switches, traffic lights and relay equipment located in relay cabinets, is greatly affected. It should be noted that the failures in the devices against the flow of rejections under the influence of the unit are minimal, and the devices work stably. Stabilization and even reduction of failure rates during degradation can be achieved through properly organized maintenance aimed at restoring the characteristics and performance of system devices. The results of statistical analysis of the operation of electrical interlocking devices and systems provide information that allows to more accurately determine the causes of accidents, objectively justify the frequency of maintenance of devices, evaluate the maintenance tactics and methods of the operating system [1].

In this work, a model railway is vitally modeled with APN (automatic Petri net) and control and control theory is applied to signal lights, transmitters and route selection. This model can be converted to PLC code using Token Passing Logic (TPL) [2]. Prohibited situations cannot be enforced using this formal approach, and only safe situations can be reached where human error can be eliminated. For additional research, complex railway stations can be subdivided and easily modeled in this way. In addition, this work can be considered as the application of the official method to a real railway station, as the design will then be installed at the railway station without traffic lights used by the Turkish State Railways [3].

Despite scientific and technological progress in the application of computer technology and crystal-based multifunctional systems, relay control kits occupied a leading position in the field of railway signaling and blocking in the landscape of the former Soviet Union. A universal simulation environment for relay-contact circuits is proposed to test the above during both development and operation. This environment has a simple interface and is easy to use, ie you need to draw the tested circuits and set the parameters of the above elements. The use of an advanced modeling environment has shown that we can improve the performance of automation circuits on the High Speed Rail, and that some design flaws only manifest themselves in non-standard operating conditions. The simulation environment can be used not only to investigate the state of relay contact circuits, but also to solve problem-solving automation problems. At the same time, it is expedient to connect it with existing devices of permanent control systems of railway signaling and blocking devices [4].

The development of the blocking system is explained taking into account the functional safety requirements of CENELEC standards, in particular EN 61508 and EN 50128 related to rail. The voting system, which is part of an advanced interlocking system, consists of two non-crashing PLCs, the operation codes of which are determined using the Automatic Petri Network (APN) methods adopted by EN 50128 as a semi-formal method. The communication between the traffic control centers is achieved by a master supervisor, who connects the railway area with the PLCs, compares, reviews and implements all decisions. The resulting blocking program is tested and validated using both a blockchain Test Program (ITP) simulator and a small-scale hardware simulator for the railway garden set up at the Istanbul Technical University's Industrial Automation Laboratory [5].

The use of artificial intelligence (AI) will undoubtedly develop in the future. The planned S2R project will consider the use of SI for:

• Improving safety in self-driving vehicles (for example, by teaching the vehicle to detect obstacles related to the state of infrastructure associated with several variables);

• development of large data applications on railways (eg forecasting repair, Building Information Modeling (BIM) and optimization processes);

• detection of cybersecurity intrusions (for example, through exchanges with a large number of intelligent objects connected to the IP);

• flexible distribution of bandwidth (power) over the network;

• providing innovative real-time flexible services (for example: combining the full capacity of long block trains along freight routes - starting from railway freight corridors - flexible services - stopping and moving at automated terminals);

• Staff planning management to optimize the use of existing / appropriate rolling stock and existing staff within the network and within this service offer.

Another direction for the future development of digital railways is their joint development with space technology. In fact, for almost all optimization calculations of train movement, it is extremely important that the train has an accurate position on the ground, centimeter accuracy, and an accurate measurement time similar to an atomic clock in almost real time.

Since so much has already been said about the Internet for a digital railroad, it is worth focusing the reader's attention on general development trends that will determine many things. The figure shows the expected growth in the application of the five fastest growing digital technologies in the world. From the point of view of the development of a digital railway, it is quite possible to focus on this information [6].

Presents a method and results of a reliability analysis that touches on the characteristics of various blocking architectures related to machine safety and availability. It shows the advantages of 2oo3 architecture for systems with high requirements in terms of both security and availability. Subsequent studies are being conducted on the interface between intermediate locks (eg, circuit breaker) and protected machine subsystems (eg, magnetic amplifier circuits), including detectors. The Monte Carlo approach is further developed to validate different studies. In addition, the validation of the models, in particular the basis of the model, must be linked to the assumption of flawless voting [7].

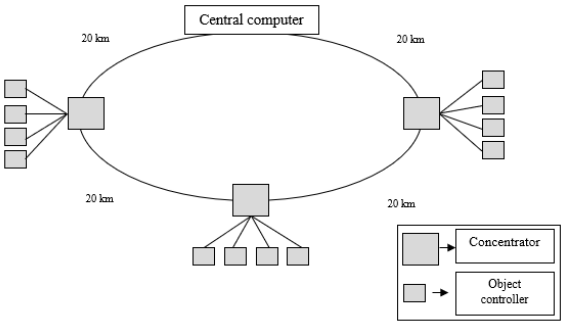
Microprocessor system - designed to ensure the safety and control of train movement at stations and apartments of any size, configuration and purpose, as well as for coordination stations for trains with different types of traction. The system combines the functions of automatic and semi-automatic blocking, remote management of areas and parks of stations, as well as the ability to remotely control and integrate with higher-level systems (dispatch centralization and management).

Until now, the advantages of centrifugal microprocessor systems for traffic lights and intersections compared to relay-type centralization were clear.

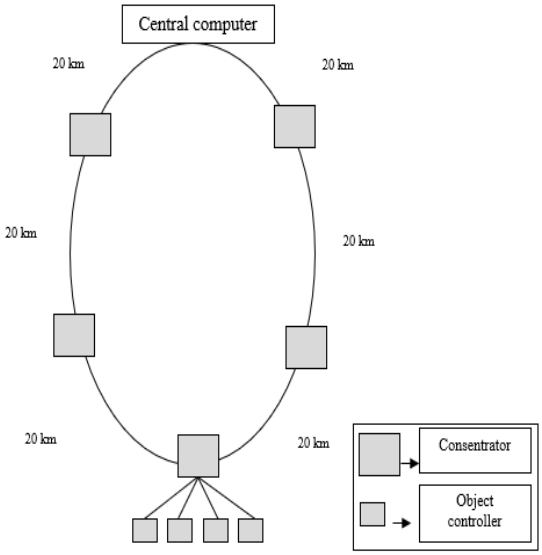
- A higher level of reliability (robustness) due to the duplication of the CPU, which is the heart of many nodes, including centralization, and the continuous exchange of information between this processor to ensure the safe movement of trains, control and management of facilities
- Possibility (probability) of managing many stations and road facilities from one place of work
- Integration of signaling, centralization and blockchain management with roadside devices and the possibility of ensuring security in a single-processor unit with devices
- Extensive set of technological functions, including the closure of the route without opening the traffic light, blocking the crossroads in the required condition, prohibiting the performance of traffic lights, isolated sections (sections) to exclude the issuance of the route
- High level of information for the operational and technical staff on the status of imb facilities at the

station, the possibility of transmitting this or that information to the regional control center
- Possibility of centralized and decentralized placement of control facilities for the management of station and road housing facilities. The decentralized placement of facility controllers allows for a significant reduction in the specific rate of cable consumption per centralized junction.
- Simple graft ratio with higher level control systems

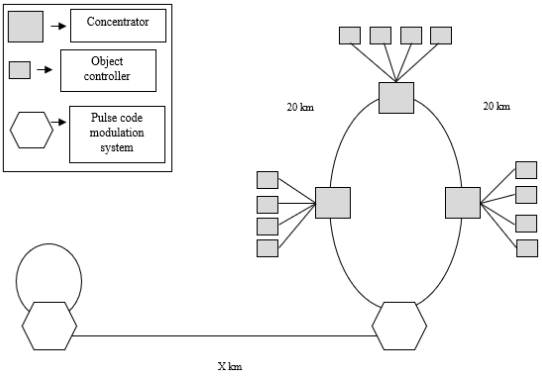
- Ability to archive the uninterrupted work of maintenance personnel in the management of all train situations and facilities at stations and road apartments
- Diagnostic control installed on the objects of control and management, the condition of centralized hardware
- Possibility to register refusal numbers of trains running at station and road apartments, as well as at control facilities
- The relatively small size of the equipment, the fact that the building is 3-4 times smaller for its placement, allows you to change the old type of centralization without building new electrical interlocking posts.
- The size of the construction and installation work is much smaller
- Convenient technology for checking the dependence of the model without assembly due to the use of specialized tuning tools
- Reduction of downtime of stations and road facilities in case of changes in the road development of stations and related dependencies between intersections and signals
- Use as a data transmission medium not only with copper wire cables, but also with optical fiber cables to controlled objects in control devices and vice versa
- Possibility of obtaining working parameters from the archive of IMB field devices without forecasting their future condition or planning of repair works without allowing complete failures in the operation of these devices.
- Reduction of operating consumption due to reduction of energy capacity, reduction of the number of electromagnetic relays, application of modern non-serviced power supplies, elimination of large mechanical controls and large control panels and manipulators with buttons
- contactless control of switches and traffic lights based on intelligent object controllers.
- Organization of communication according to the principle of communication, maintenance of communication channel.
- Advanced system diagnostics that allow you to detect equipment conditions before failure.
- Possibility of centralized or decentralized placement of equipment. High level of availability: the use of standard industrial modules, testing of software and hardware complex is carried out in the factory, the enterprise is provided with fully tested and selected equipment. Facility controllers monitor traffic lights, turnouts, crossings, road circuits, etc. Performs functions for the management of floor objects such as. Each object controller can manage one or more objects. The maximum distance between object controllers and the CPU is not limited. Decentralized placement of the control minimizes cable use and reduces the risk of induction currents interfering with signaling devices. When a fault is detected in advance, the built-in self-diagnostic system automatically places the damaged element in a separate print cycle. The system can be equipped with surge protection devices.



Typical configuration of communication loops



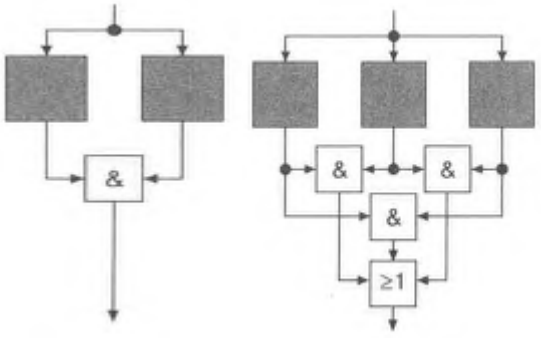
Configuration of communication loops in case of long distance



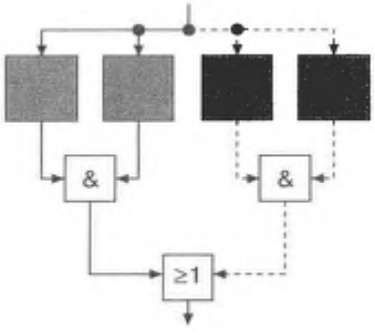
Configuration of communication loops using pulse code modulation equipment in case of long distance.

Compared to mechanical and relay centering, the application of microprocessor centering semiconductor element base reduces the security level of the system. Low voltage electronic components have a high sensitivity to external influences. It is difficult to know. Over time, the working characteristics of electronic components change. The complexity of the electronic components makes systematic errors in execution also difficult to control the process in the technical system and to change the situation. To some extent, the principles of sabotage and towing are used to overcome some of these shortcomings. In the redundancy system, one or the same function is performed on different hardware channels, and the result is compared with each other. Towing in microprocessor complexes primarily eliminates the possibility of accidental errors. Hardware backup is used in almost all microprocessor systems, the following options are used in the planning of this system.

- 2oo2 system - In such systems, the responsible functions are processed on two independent computing channels and the security of the obtained results is compared. In case of compliance, the output of the system includes the agreed result, and in case of non-compliance, it makes the system safe.
- 2oo3 system - Functions are processed on 3 independent channels. If a channel is rejected, that channel is isolated. In this case, the centralization works as a 2oo2 scheme until the rejected channel is restored.
- 2x (2oo2) is a double system of two, in which case the 2oo2 subsystem is active and the other remains in reserve. If a failure occurs in the active subsystem, it is isolated, and the processing of the function takes place in another backup subsystem.

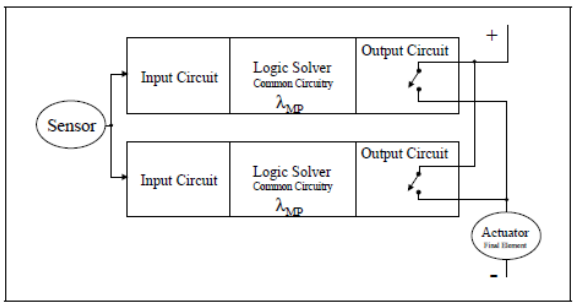


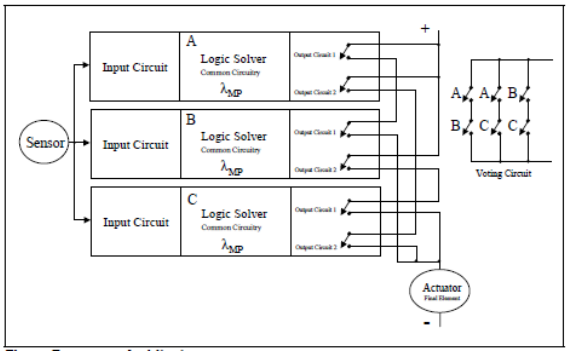
2oo2 2oo3



2x(2oo2)

Microprocessor system backup



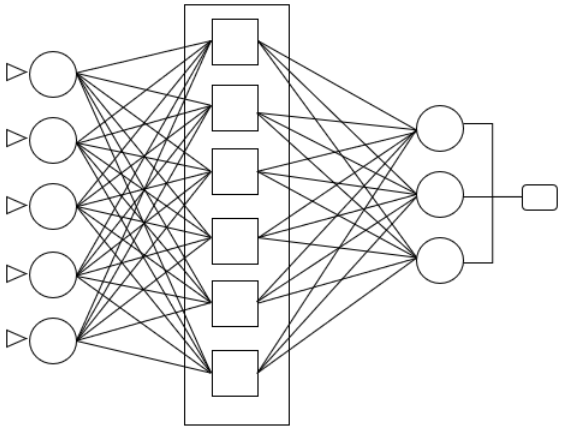


2oo2 and 2oo3 architectures

In a control system, the nonlinear mapping ability of neural networks can be used to accurately describe, act as a controller, optimize calculations, model nonlinear objects that are difficult to draw conclusions or misdiagnose, or both to match certain functions. Neural network-based intelligent control refers to the management of this network alone or to the integration of the neural network, as well as other intelligent control methods. The main types of control are the following forms.

1. Direct feedback control of the neural network. This is a way to directly implement intelligent control using only neural networks. In this method of control, the neural network is used as a direct controller, and algorithms are used as feedback to control self-learning.
2. Nervous network specialist system control. Expert systems are good at expressing knowledge and logical thinking. Nerve networks are better than nonlinear mapping and intuitive reasoning. Combining the two to give the game the appropriate advantage will result in better control results.
3. Fuzzy logic control of the neural network. Fuzzy systems are good at expressing logic directly and are suitable for expressing knowledge directly. Neural networks are better at learning to express knowledge indirectly through information. The first is for top-down expression, and the second is for bottom-up learning. Therefore, their integration can complement each other and better develop the intelligence of the management system. There are three ways to connect fuzzy logic with a neural network. First, fuzzy control using a fuzzy neural network to control fuzzy thinking. This method uses a neural network to directly design multiple member functions and connects the neural network as a member function generator in a fuzzy control system. Second, use a neural network to

remember control of fuzzy rules. Third, the fuzzy controller settings are optimized using a neural network. In addition to the above-mentioned membership functions and fuzzy rules, factors affecting management performance in fuzzy control systems also have control parameters such as error variation quantization factor and output scale factor. These can be optimized using the neural network parameters optimization calculation function to improve the performance of the fuzzy control system.
4. Control of the sliding mode of the neural network. Variable structure control can be considered as a special fuzzy situation, and therefore belongs to the category of intelligent management. Nerve network slip mode control is the control of the slip mode of the neural network. This method classifies the control or state of the system, changes and selects according to changes in the system and the environment, uses the learning ability of the neural network, and improves the transition curve of the sliding mode by self-learning in an uncertain environment. to improve the control effect of the sliding mode.
The application of the idea of a neural network related to security is that the information for access is transmitted through intelligent sensors and a learning algorithm is released. The algorithm automatically analyzes the data structure and creates a relationship between input and output. Neural networking is a very powerful modeling method that allows you to build very complex dependencies.



Neural network (triple perceptron that transmits information directly).

Input solid source variables - rail circuit or axis meter, traffic light signals, condition of switches, condition of barriers and road blockers in the passage, signals from devices detecting hot buckets, signals of tracking devices or tracks on bridges and tunnels serves to enter the values of the data that are empty. It then sequentially develops neurons in the intermediate and output layers. In the intermediate layer, the values contained in the data from all inputs are collected in advance in a knowledge base (DB) with software. The knowledge base determines the output mechanism of the solution embedded in the system. These components determine the two main intellectual characteristics of the system: the ability to store knowledge about anything and the sequence of operations on this knowledge. Knowledge-based systems include systems that can learn, grasp new knowledge, expand BB, and adjust knowledge to changing conditions and events in the field of research.
At network nodes, the neuron calculates its activation value, taking the number of outputs from the previous layer. The activation value then uses another activation function, resulting in a neuron output. Once the entire network is complete, the output values are taken from the elements in the last layer, generally for the output of all networks.

CONCLUSION

A modern electronic locking system must be extremely flexible and measurable to ensure that it can be adapted to different sizes, different devices, different environments, different signal principles and even different applications. In addition to being suitable for critical operation in terms of safety, railway systems must also be highly reliable and accessible, and in most cases must meet strict requirements in real time.
The intelligent complex allows the transition to significantly new technologies for driving vehicles, minimizing the negative impact of the human factor, the efficiency and economy of management, operational reliability of traction personnel, safety of train operation, as well as solutions. In the near future, the use of artificial intelligence, neural network systems with the centralization of the microprocessor will help solve the problem of staff shortages of drivers and assistants. New technologies for driving trains can increase the carrying capacity of railways and save 5% to 15% of energy resources in the construction of trains, greatly facilitate the work of train drivers, increase traffic safety and pave the way for innovative transport development. industry. The importance of new technologies to operate trains is very high.
As a result, the advantages of neurocomputers based on the idea of a neural network are as follows:
Ensuring a high level of accuracy with the parallel operation of a large number of computing devices
The neural network has the ability to learn, and this is done by adjusting the parameters of the network
The neural network is highly resistant to rejections and external influences.
The simple structure of individual neurons allows the use of new physical principles of information processing for the hardware realization of the neural network.

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