The Reliability of Critical Systems in Railway Transport Based on the Track Rail Circuit

Ryszard Mielnik, Maciej Sulowicz, Krzysztof Ludwinek and Marek Jaskiewicz

Abstract This paper presents a system for monitoring and control of unoccupied railway track of automatic railway crossing signaling devices. The most important task of this system is to ensure the safety of rail and road traffic. This solution belongs to the class of critical systems, and is particularly important not only for safety reasons to prevent the collision of railway vehicles and road wheeled, but also entails various economic aspects. The first part of the article raises issues related to the safety of rail transport process. It then discusses the possibilities of using rail circuit to determine unoccupied section of the approach and the distance of the rail vehicle from the railroad crossing. Structure and functionality of automatic railway crossing signaling devices on a level crossing were defined. The synthesis of safe measurement control digital system is based on a dynamic model using Petri net. Factors of reliability and discusses the advantages of the proposed system solutions were estimated.

Keywords Track rail circuit · Wave impedance · Measuring system · Critical systems · Railway traffic safety · Railway control systems · Discrete event system · Petri nets · Realtime systems

R. Mielnik (✉) · M. Sulowicz
Institute of Electromechanical Energy Conversion, Cracow University of Technology, Cracow, Poland
e-mail: rmiel@pk.edu.pl

M. Sulowicz
e-mail: msulowicz@pk.edu.pl

K. Ludwinek
Faculty of Electrical Engineering, Automatic Control and Computer Science, Kielce University of Technology, Kielce, Poland
e-mail: k.ludwinek@tu.kielce.pl

M. Jaskiewicz
Faculty of Mechatronics and Mechanical, Kielce University of Technology, Kielce, Poland
e-mail: m.jaskiewicz@tu.kielce.pl

D. Mazur et al. (eds.), *Analysis and Simulation of Electrical and Computer Systems*, Lecture Notes in Electrical Engineering 452,
https://doi.org/10.1007/978-3-319-63949-9_25

1 Introduction

Speed, comfort, and safety of movement of people and goods in the rail transport is a very important issue for the economic development in each country. The result is therefore the requirement of rolling stock, railway traffic control equipment and track infrastructure, which will ensure a high level of reliability and the required safety level of the transport process.

Currently used railway traffic control systems belong to the class of computer control systems used in critical processes [22]. This type of systems is particularly important in preventing railway accidents in which people die and there are large material losses. In critical industrial processes measuring control digital systems (MCD systems) are commonly used [22]. These systems are built on the basis of hardware platforms such as PLCs, industrial computers, and embedded systems [22]. They owe their rich functionality to implemented software utility. The quality of work MCD systems is affected by the hardware platform used and software of MCD systems applied [8, 9, 19, 24]. A major problem in the implementation of MCD systems is not only writing of the design, construction, and testing, but also testing the system as a whole. Ensuring high reliability of the software and the reliability of the entire MCD systems is required especially in critical applications. Improper function or failure of the system during its operation can lead to malfunctioning of the controlled process. The effect of this may be human and material losses. One of the critical processes is rail transport [3, 5, 14, 24]. In this process, the basic requirement is to ensure the safety of the shipping process. The second essential requirement in this process is to ensure adequate reliability of the process, i.e., that trains and all kinds of rail vehicles move in accordance with the approved mining plan-timetable [5, 18, 24]. Any defect traffic control devices (which provide the planned course of the transport process) influences the movement disorder plan-timetable. Smooth and trouble-free transport process is affected by many factors related to the rolling stock [6, 12, 13, 16, 19], traction, track infrastructure [7], and railway traffic control equipment [1, 5, 14, 15, 17, 24].

The purpose of this article is to present the possibilities of using the system of monitoring and control approaching section of the automatic railway crossing signaling devices (ARCD devices). These devices are built over at the one-level crossings so that the devices MCD systems generate appropriate signals to warn drivers of impending rail vehicle. The present system provides security by closing the passage in the event of damage to the MCD systems and information to the railway driver to reduce the speed of the vehicle so as to avoid a train crash.

According to the station from 11 February 2015 Poland has 15,403 crossings and only 1316 railway crossings are secured by automatic railway crossing signaling devices. Among them, there are practically none constant-time automatic crossing devices, which provide constant-time warning drivers of closing of the passage. Therefore, it seems reasonable to develop and implement such system solutions.

2 The Process of Rail Transport

The process of rail transport takes place on a network of Polish Railway Lines (PLK), and it allows the movement of passengers and goods in Poland. It also allows the implementation of transport services in terms of their transit areas of Europe. Traffic on the railway lines must be properly planned, controlled, and implemented. The implementation of these requirements provides a process for railway traffic control [5]. This process not only provides timely and reliable realization of the planned rail traffic on the roads driving trains and warehouses maneuvering, but must first and foremost ensure the safety of the movement. The main factors for the preparation of a safe road driving for rail vehicles are [5]:

- correct setting organization, setting, and releasing waveform driving,
- reliable implementation conditions guaranteeing safety.

Control of the fulfillment of conditions for the implementation of safe driving trains can be implemented in a way that is not dependent on or addicted to [5, 18]. The method is not dependent when the realization of the conditions driving safety rests with the personnel, while in the addicted method implementation of these conditions is carried out by means of railway traffic control devices (RTC devices) [5]. This entails that the damage to components of RTC devices does not result in their transition endangering the safety of traffic. Addicted way to control the implementation of safety RTC devices shows greater reliability of repeated action than when done by people. In addition, the control method depending on the security conditions is more reliable than not implementation [5]. Therefore, the larger the scope of the addict how to implement the safety requirements included in the technical solutions of the RTC devices while providing reliable their implementation the greater safety signaling system can provide [5].

Currently, designed and built RTC devices and systems must meet appropriate levels of safety and reliability; and as devices based on the platform of the computer and the PLC should be considered an appropriate choice of features of the system for both the underlying hardware and software of a system. The Technical Committee of the Organization of Engineers Rail Signaling (TC-IRSE) developed levels of security RTC systems depending on the effects of potential failures and errors resulting in the system, system functions, security level, and intensity of damage λ for one piece of the system (e.g., driver switch-point) [5]. According to TC-IRSE fourth, a very high level of security (Fail-safe) is required for security systems railway traffic, and the effect of potential damage or system errors is the loss of human life or health, or very large material losses and the failure intensity λ element (module) system cannot be greater than 10^{-11} [5, 18]. This level of security is required, e.g., For devices setting the police station of train traffic, monitoring, and control systems unoccupied tracks and switches or automatic signaling device are spared [5, 18].

3 Monitoring and Control System for Unoccupied Tracks

The basic condition for ensuring the safety of rail traffic is that at any given time on the road only one rail vehicle moves, and that in this way there is no other rolling stock or other obstacles. Track provides checking this condition Track circuit is an electrical system designed to monitor the condition of a particular section of railway track, which is part of a route or rail vehicles [5]. Checking the track circuit section concern the seizing of the rolling stock and is realized on the basis of the transformation of external criteria for designating finding rolling stock into electrical signals that can be used in MCD systems, information or other [5]. Most of the track circuits also allow continuous monitoring of cross level covered by the system of electrical track circuit, and also the principle of being on the track other obstacles than the rolling stock. Such monitoring can detect, e.g., rail fracture. Then, an electric track circuit will lead to the generation of the busy signal of the segment which is safe for the traffic situation. For measuring the following distance of the rail vehicle from the end section of the track, you can use the rail track circuit, which is part of devices interaction relationship track-vehicle of automatic railway crossing devices on railroad crossing. The general track rail circuit is shown in Fig. 1 [11, 14].

Shown in Fig. 1 the track circuit is supplied with a sinusoidal AC voltage U_1 [5, 11]. Entry of a rail vehicle (rolling stock) on the circuit section of rail with a length l results in short-circuiting the set of circular cross level on a variable-length l_p. This alters the input impedance of the circuit. To determine the input impedance of the binding equation used voltages and currents at the ends of the circuit, by the means of the transmission line equation [2]. Because in the circuit, $\overline{U}_2 = 0$ so that the input impedance of the circuit rail is [5, 11]:

$$\overline{Z}_{\text{we}} = \overline{Z}_f \cdot \text{th}\overline{\gamma} \cdot l_p \tag{1}$$

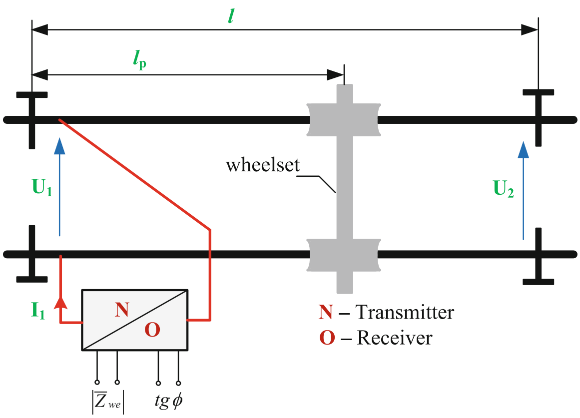


Fig. 1 A basic block diagram of track rail circuit

where $\overline{Z_f}$—wave impedance circuit, $\overline{\gamma}$—propagation constant.

The results of the analysis of the function of impact given in the work [11]:

$$\left|\overline{Z}_{\text{we}}\right| = f(l_p) \tag{2}$$

$$tg\,\phi = \text{Arg}\,\overline{Z}_{\text{we}} = g(l_p) \tag{3}$$

The results of the analysis of the function of impact in work [11] were obtained on the assumption that:

- a section of the track is separated from the track by means of insulated connectors on both ends and moving rolling stock takes place from the end of the track circuit to railway pass,
- a place of measuring the change in the module $\left|\overline{Z}_{\text{we}}\right|$ and $tg\phi$ the input impedance of the track circuit is the beginning of a variable-length l_p,
- examination of variations module and an argument input impedance $\left|\overline{Z}_{\text{we}}\right|$ were carried out in the state of fixed operating circuit for sinusoidal signal supply circuit with a frequency that ensures the uniqueness of changes in the studied parameters input circuit,
- a circuit rail is perfectly contained within a l_p of passing the first axle of a vehicle,
- the mathematical model of circuit rail describes the symmetrical long line with distributed parameters uniformly along a section of length l,
- a rail circuit is powered from an ideal AC voltage source,
- a net traction does not effect on the analyzed rail circuit.

Figures 2 and 3 show the relationship between modulus and argument of input impedance for typical parameters of track subgrade and for two different input signal frequency. Simulation of rail circuit operation was carried out for the typical parameters of the track subgrade for two power frequency: 500 and 1000 Hz. The resulting waveforms are shown in Figs. 2 and 3. The red color is a graph of the input signal f = 500 Hz, and the blue color for f = 1000 Hz.

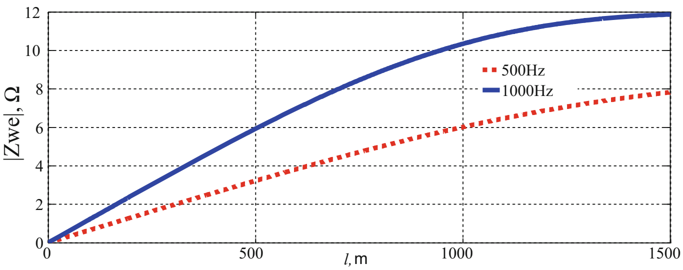


Fig. 2 $\left|\overline{Z}_{\text{we}}\right|$ impedance modulus change as a function of distance l

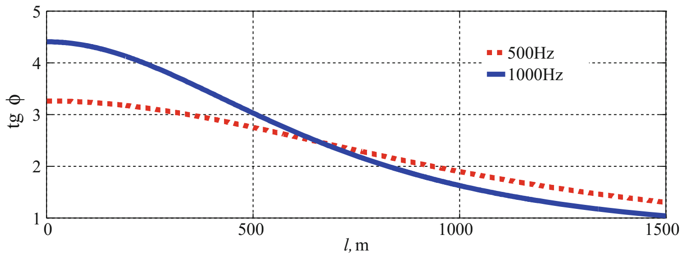


Fig. 3 tgϕ change as a function of distance l

In a real system, a frequency signal should be chosen so that the operation of the measuring system was the best, i.e., to obtain uniqueness impedance measurement. To ensure the safe operation of the monitoring section of track, one channel of measuring system measures the module of impedance, and the second phase shift. Only two correct signals obtained from the measurement of impedance modulus and shift, informing about the whereabouts of the vehicle (basically the first axis) and served on a secure, two-channel measuring and control system helps ensure the correct and actual value of the distance of the rail vehicle from the beginning of the rail circuit.

The conducted simulation analysis [11] runs a function module $\left|\overline{Z}_{\text{we}}\right|$ and $tg\phi$ of input impedance showed that:

- for track circuits, you can get a clear run function impact $\left|\overline{Z}_{\text{we}}\right| = f(l_p)$ and $tg\,\phi = \text{Arg}\overline{Z}_{\text{we}} = g(l_p)$ on approaching sections length 1500 m, provided the selection of the frequency of the power supply circuit, according to the border conductance track subgrade,
- for a given parameter, which is the argument of input impedance, designated effective length of the track circuit is greater than for the module of the input impedance (under the same conditions track subgrade). A similar relationship exists for the argument and the module of the wave impedance,
- in the case of simultaneous use of both functions influence should be the frequency of the power supply circuit to choose in order to ensure the uniqueness of changes in impedance modulus, as this parameter is achieved shorter useful length of the track section.

The above results of the research function of the impact $\left|\overline{Z}_{\text{we}}\right| = f(l_p)$ and $tg\,\phi = \text{Arg}\overline{Z}_{\text{we}} = g(l_p)$ point to the possibility of using the circuit rail, as part of the impact relationship track—a vehicle for self-crossing signaling devices. Another issue that needs separate study is selecting the frequency of the signal power. This is because changes of amplitude and phase angle from changes parameter pf track and the effect of interfering signals from other devices SRK and electric rolling stock.

4 Equipment of Automatic Railway Crossing Signaling Devices

Traffic safety at a level crossing is provided by automatic signaling light with dams of the road, called automatic railway crossing signaling devices (ARCS devices). These devices operate automatically, i.e., without human intervention.

Figure 4a shows a typical layout of equipment ARCS devices on level crossing category B of double-track line. These are [14, 15]:

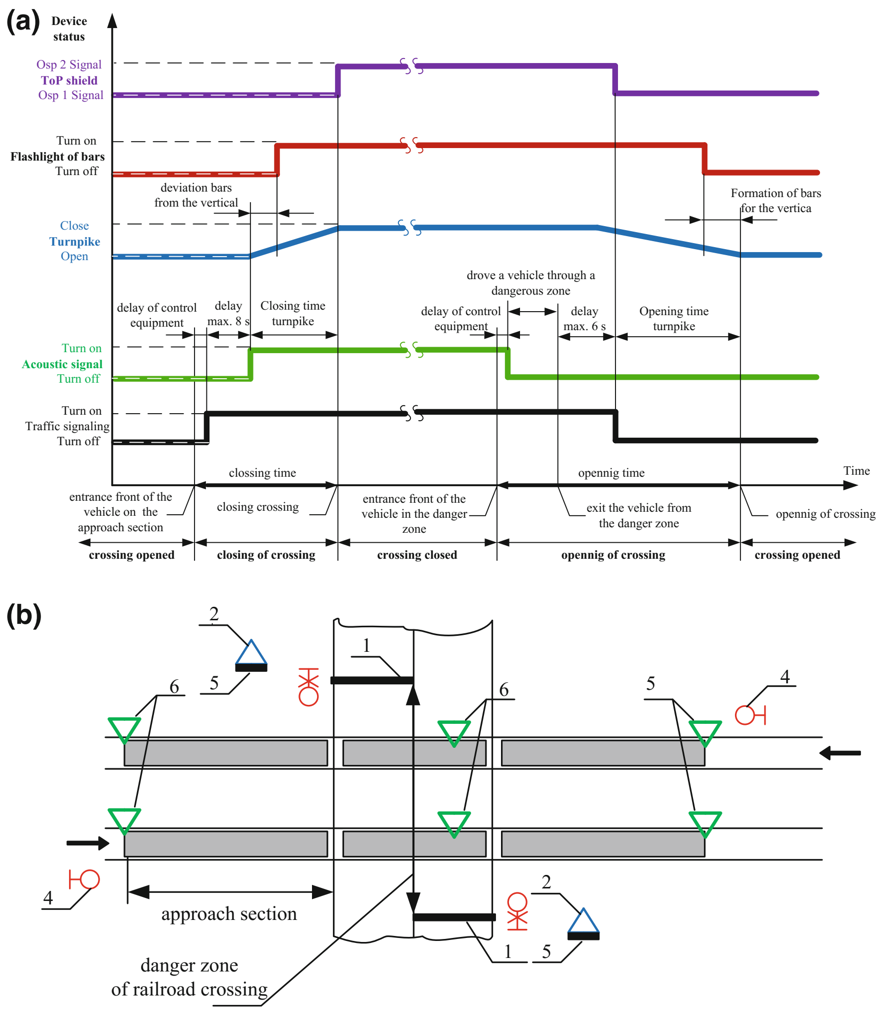


Fig. 4 Equipment of automatic railway crossing signaling devices: **a** time diagram of operation devices, **b** layout of level crossing devices

- dams of road—(1),
- acoustic indication warning drivers—(2),
- optical indication warning drivers—(3),
- track sensors, which detect entry of a rail vehicle on a approaching section—(5),
- sensors track stating occupation and leave the danger zone of a railway crossing through a railway vehicle—(6),
- optical indication warning drivers of rail vehicle, ToP—(4).

With this equipment of one-level railroad crossing in the device shown in Fig. 4, it is possible to provide a warning road users (drivers) before approaching rail vehicle.

4.1 Warning Users of Roads

Warning road users are done from the moment of entering of the front of a rail vehicle in the approach section, until the moment when the whole rail vehicle crosses the danger zone. This process consists of following phases [3, 15, 18]:

The process of closing the crossing:

- rail vehicle approaching the crossing, crashing into sensors track approach section, will launch controller of MCD system, resulting in the inclusion of red light on the road signals and turning on sirens sound signal,
- after 8 s delay electric drives that leave the bars dams are activated,
- the deviation of bars dams from the vertical position results in turning on the lights of lighthouse on bars,
- positive verification: closure of the dams in the horizontal position, shining lights on the road signaling, and lighthouse on bars will turn on the signal OSP2 on the signaling ToP.
- If during the warning process a rail vehicle on the second track is detected, the closure process will be continued.

The process of opening of the crossing:

- after max. 6 s from the exit of the rail vehicle from the sensor track of the crossing danger zone, lights on the road signaling are switched off and lifting of bars dams begins,
- turning off lights lanterns on drams takes place when they reach the vertical position,
- a change is also a signal to the Top signaling,
- positive verification: the state of dams in the vertical position, turning off the lights on the road signaling and lighthouse on drams, causes turning on the signal OSP2 on the signaling ToP.

From the point of view of ensuring the safety of road users starting the warning process and closing of the crossing must be made with the appropriate lead time.

This time is defined as pre-warning time t_0 [5, 18]. When calculating this time, it is assumed that the rail vehicle is running at the maximum permissible speed of force on the route of the railway and road vehicles leaving the danger zone passing move at the minimum speed. In [5, 18], it is assumed that the pre-warning time t_0 is

$$t_0 = t_n + t_{zp} + t_{0p} \tag{4}$$

where t_n [s]—the time classes of danger zone of railway crossing, t_{0p} [s]—the delay time to be paid by the MCD controller, for electronic devices shall be 1 s, t_{zp} [s]—the constant value of inventories time, shall be 10 s.

This t_0 time for the station's conditions, according to the decree of the Ministry of Communications [18], cannot be less than 30 s and because of practical reasons not more than 90 s. Thus, the time should be included in the range:

$$30\,\mathrm{s} < t_0. < 90\,\mathrm{s} \tag{5}$$

The general structure of the block diagram under consideration automatic railway crossing devices is shown in Fig. 5a [14, 15]. Figure 5b, c shows the action rule (in the form of conditional expressions *IF the condition THEN is action*) of linguistic model of the closing (Fig. 5b) and the opening (Fig. 5c) process of railway crossing.

4.2 The Dynamic Model of an Automation Railway Crossing Signaling Devices

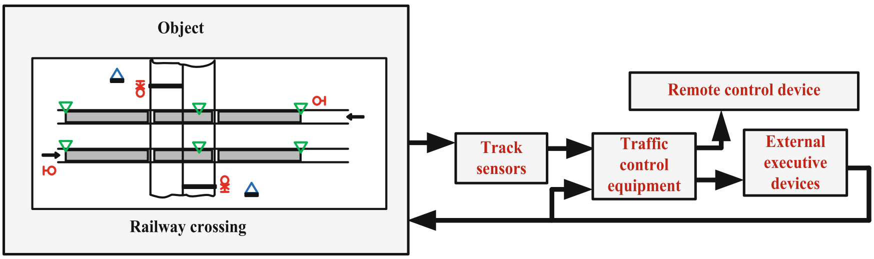
Modeling of dynamic behavior of discrete event system requires the use of tools for modeling time constraints. One class of Petri nets allowing such modeling is a class of simple time, Petri net [4, 10, 21]. Using the knowledge and experience of the development of reduced net an automatic railway crossing devices, using the methodology of the construction of hierarchical nets—from the particular to the general (bottom-up) [20]—a simple time net for these devices is developed. This net, (Fig. 6), highlights two fundamental processes: the process of moving rail vehicle and the control—supervising process of an automation railway crossing signaling devices.

Symbols of time Petri net structure is shown in Fig. 6, means:

Places:

p1—away from the station of rail vehicle on the track,
p2—the rail vehicle is before approaching section,
p3—the rail vehicle is on approaching section,
p4—the rail vehicle is on approaching section,
p5—message "close" crossing devices,
p6—status of crossing devices is "open",

(a)



(b)

(1) **if** *the rail vehicle is on the approach section* **then** *warn.*
(2) **If** *warn* **then** (*turn on the road signaling device*) and (*measure delay of 8 seconds*).
(3) **If** *measured delay of 8 seconds* **then (***turn on the siren signal*) and (*turn on the electric drive of rods*).
(4) **If** *rods are deviation from the vertical* **then** *turn on the rod's electric torch*.
(5) **If** (*turn on the road signaling device*)
and **(***turn on the siren signal***) then** *view signal Osp 2 on Top signaling* device.
and (*rod's turnpike closed*)
and (*turn on the rod's electric torch)*

(c)

(6) **if** *the rail vehicle drove into the danger zone* **then** *turn off the road signaling device*
(7) **if** *the rail vehicle lives the danger zone* **then** *measure delay of 6 seconds*
(8) **If** *measured delay of 6 seconds* **then (***turn on the electric drive of rods*)
and **(***turn off the road signaling device*)
(9) **If** *rods are in the vertical* **then** *turn off the rod's electric torch*.
(10) **If (***turn off the road signaling device*)
and **(***turn off the siren signal***) then** *view signal Osp 1 on Top signaling* device.
and (*turn off the rod's electric torch)*
and (*rod's turnpike opened)*
(11) **if** *viewed signal Osp 1 on Top signalling* ***then*** *the railway crossing is opened.*

Fig. 5 **a** The block diagram of an automatic railway crossing devices, **b** rules of the process of closing the crossing, **c** rules of the process of opening of the crossing

p7—entry rail vehicle from the track to the station.
p8—the rail vehicle is before the danger zone of crossing devices,
p9—status of crossing devices is "close",
p10—the rail vehicle on the track,
p11—the rail vehicle exit from the danger zone of crossing devices,
p12—message "open" crossing devices,
p13—track is free (no rail vehicle on the track).

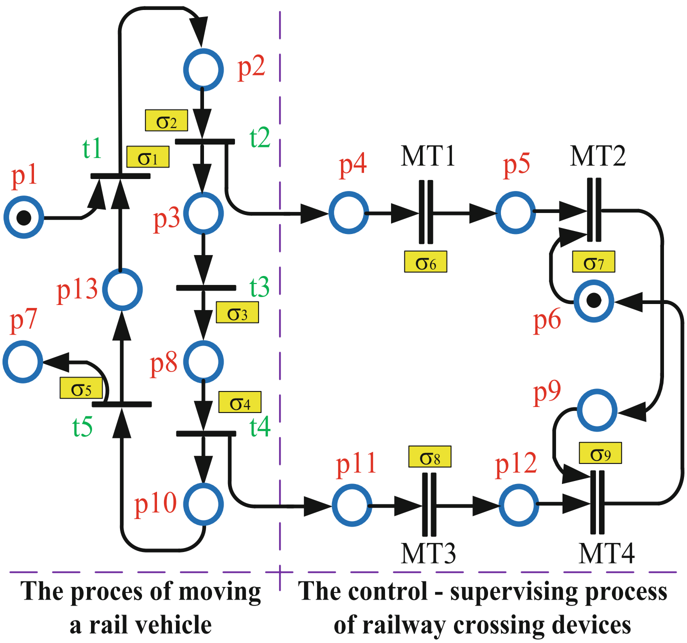


Fig. 6 Simple time Petri net of an automation crossing devices

Transition:

t1—ride a rail vehicle by track to approaching section,
t2—moving the front of rail vehicle approaching section,
t3—drove a rail vehicle through a approaching section,
t4—drove a rail vehicle through the danger zone of crossing devices,
t5—leaving the track by a rail vehicle.

Microtransition:

MT1—detected by measuring system entry rail vehicle to the approaching section,
MT2—making process of closing,
MT3—detected by measuring system exit rail vehicle from the danger zone of crossing,
MT4—making process of opening.

The process of movement of the rail vehicle corresponds to the place p1, p2, p3 and p7, p8, p10 of simple net time—Fig. 6, which is associated with the entry vehicle to the approaching section from trial, entry, and exit from the danger zone of crossing and travel and leaving trail. Places p4, p5, p6 and p9, p11, p12 correspond to the control—executive process of an automation crossing devices. Macrotransitions MT1 and MT3 model subprocesses of acquisition of measurement signals from the sensors track section approaching and passing the danger zone.

Macrotransition MT2 is responsible for closing the passage subprocess and macrotransition MT4 for subprocess of opening run. For transition and macrotransition of this simple time net appropriate static times σ_n are assigned. After these times, transition and macrotransitions are performed [21]. These times are modeling delay times associated with the processing of signals and data.

5 The Hardware and Software Structure of the System

In the case of small MCD systems, which could include controller of ARCS devices, allowance for the detection of a single error, which is the result of damage to the structure of the system, is required. To implement this requirement, the structure of the hardware system with a "vote" and working in the structure of "*k* of *n*" [14, 15] is adopted. The practical realization of this layer was applied by redundant, dual-channel hardware structure of voting "2 of 2", as shown in Fig. 7.

Figure 7a in the illustrated layer structure hardware controller of ARCS devices distinguished:

- two independent sensors of approaching rail vehicle, measuring the time of its directions to pass,
- two independent sensors of stating leave the danger zone for a rail vehicle,
- two modules of independent MCD controllers, performing making decision and executive functions,
- external actuators, warning road users,
- safe comparators of output signals,
- monitoring computer (remote control).

The use of transmission interfaces between modules driver channel A and B can synchronize the work of both channels, and compare internal transition states of variables and time stamps. As illustrated, the hardware structure mirrored all inputs and outputs. Outside control signals of the external equipment of warning road users are generated by the safe comparators. The above hardware structure also allows you to use functions of the remote control system. Overall equipment of controllers of ARCS devices may be implemented in hardware using single-chip microcontrollers, PLCs, or industrial modular computers. The general functional structure of software for the control unit to ARCS devices is shown in Fig. 7b in the form of a diagram of states. As this diagram shows, software highlights the following states: initialization of the controller, the process of decision-making processes and support the closing process control. In the work, [15] provides the possibility of using equipment and methodology state of the encoding process described above in a state diagram graphical programming environment.

For metering and control in critical applications, not only functional implementation of the tasks set is important, but also providing the required level of reliability and safe operation. This requires, therefore, estimating numerical markers of reliability and safety.

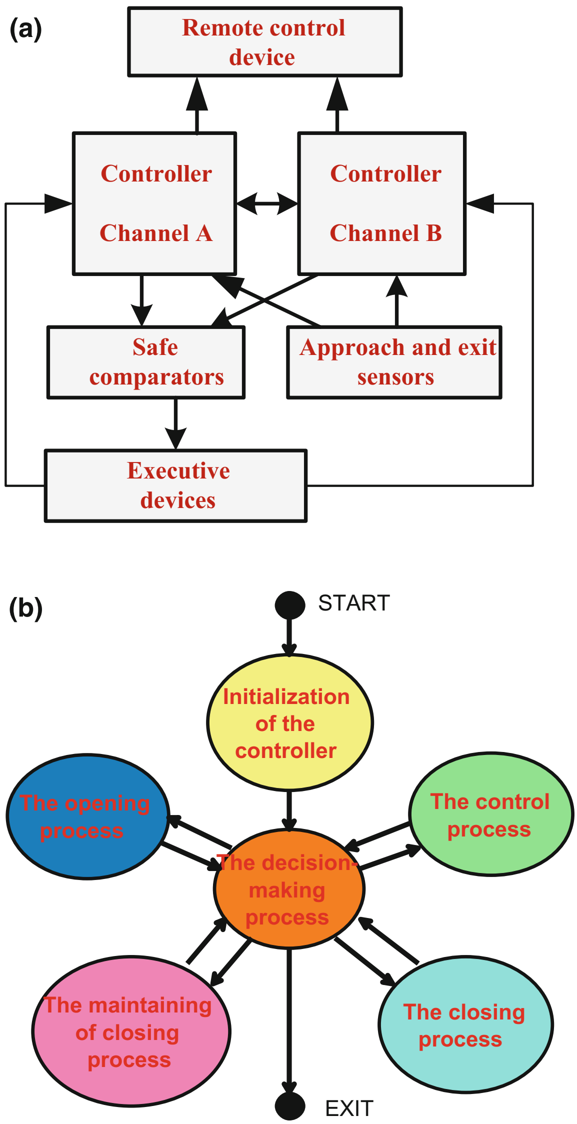


Fig. 7 **a** The hardware structure of MCD system of ARCS devices, **b** the state diagram of the decision-making and executive ARCS devices

6 Reliability Factors of the System

The basic parameter determining the level of reliability and security is the intensity factor λ of the system [5]. At the stage of development of technical guidelines system for critical uses, a minimum of requirements for the reliability and security of the system and its components (modules) should be set. For this purpose, a procedure to estimate factors reliability and safety are used. It involves decomposition of system on subsystems (modules or devices) consisting of serial-parallel structures. A simplified method of forecasting reliability is also used, which is used for newly designed systems [5]. The analysis of the reliability-developed SPS-dual-channel hardware structure MCD system of ARCS devices was performed with an accuracy of modules, which are autonomous functional blocks. General expression for the reliability of the device or module has the form [5]:

$$\lambda_U = \sum_{i=1}^{N} N_i \lambda_i \tag{6}$$

where λ_U—intensity factor damage the module or device, N_i—the number of elements i-type, λ_i—the average intensity factor damage of elements i-type.

Reliability structure is presented in Fig. 8.

The estimated intensity factor damage λ_U of the individual modules MCD system of ARCS devices are summarized in Table 1 [14, 15].

Estimated total intensity factor damage λ MCD system of ARCS devices is 3.8×10^{-5} h^{-1}. In the operating phase of MCD systems in addition to the states work correctly states may be referred to as functional states of dangerous and threatening the safety of railway traffic. Security at the system level is defined as an event opposite to the event stay the system in the states of dangerous [5].

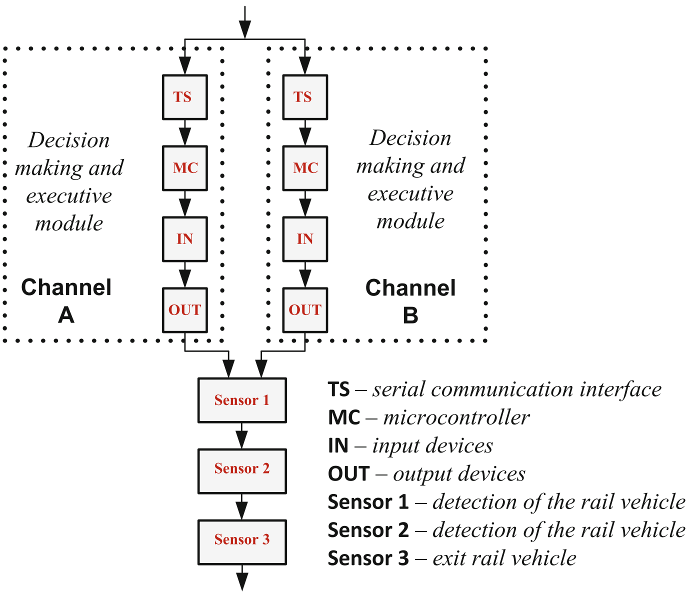


Fig. 8 MCD system reliability structure of ARCS devices

Table 1 Intensity factor damage λ_U of the individual modules MCD system of ARCS devices

Lp.	Name of module	Intensity factor damage λ_U (h^{-1})
1	TS	9.20×10^{-6}
2	MK	5.58×10^{-6}
3	IN	6.58×10^{-6}
4	OUT	2.31×10^{-6}
5	Sensor 1	3.58×10^{-6}
6	Sensor 2	3.58×10^{-6}
7	Sensor 3	3.61×10^{-6}

Assuming that the sum of the events stays in the states of the system safe and hazardous exhausts the whole set of events, the safety value S defined by the formula [5]:

$$S = 1 - P_{NB} = 1 - \lim_{t \to \infty} \left\{ \sum_{i=1}^{n} P_i(t) \right\} \tag{7}$$

where P_{NB}—the probability of system stay in the set unsafe conditions, $P_i(t)$—the probability of system stay in a state of threatening security dangerous.

The probability of presence in the set of states of the system secure, and therefore the safety of S can be determined as a function of intensity factor damage λ and response time t for the detection of an error [5]:

$$S = 1 - \lambda t \tag{8}$$

Assuming that the response time of the system to detect an error in damage equal to 0.000278 s and the estimated total intensity factor damage λ developed MCD system is 3.8×10^{-5}, the estimated value of the projected MCD system of ATCS devices security is at $S \approx 1–1 \times 10^{-9}$. Due to remaining after testing errors (logical, compiling, and side effects) [5, 23] it is extremely difficult for the software to analyze the reliability. In control systems, one undetected error software in 1000–10,000 lines of source code can be presumed, according to the [5, 23]:

- quality (qualifications and experience) development team,
- quality-possessed computer equipment,
- quality held compiler, and other utilities used to test and run the software,
- quality of the testing process.

Assuming that the disclosure of error during normal operation of the program may appear in the range from 1 month to 1 year, it was assumed that the estimated intensity factor damage λ_S of software is [5] from

$$\lambda_S = \frac{n}{1000 \cdot 0.083 \cdot 8760} \text{ to } \lambda_S = \frac{n}{10,000 \cdot 8760}$$

where n is the number of program lines. Assuming that the software program modules is approximately 1000 lines of source code in assembler language, the estimated intensity factor damage λ_S of software ranges from $\lambda_s = 1.3 \times 10^{-6}$ to $\lambda_s = 1.1 \times 10^{-5}\ h^{-1}$.

7 Conclusion

This article presents a modern solution of monitoring approach section of automatic traffic crossing signaling devices mounted on a single-level crossing of roads with the railway. This solution allows the simultaneous measurement of two independent parameters of the rail circuit of approach section. This ensures safe operation of ATCS devices. The effect of continuous measurement of changes parameters of the tail circuit of approach section is the continuous measurement of the distance of the rail vehicle from the danger zone railroad crossing. This affects the stabilization time warning drivers of railroad crossing, which may result in increasing the safety and comfort of level crossing users. You can then talk about constant-time crossing signaling that practically is not yet used in Poland. The second important aspect tackled in the article is the ability to dynamically modeling work these ATCS devices. The primary way this modeling starting from a linguistic model is a dynamic model based on simple time Petri nets. This model not only allows testing of rail vehicles passing on the railway line, but also functional testing ATCS devices. Moreover, on the basis of simple time Petri nets, it was possible to modeling the basic structure of software MCD system resistant bugs. This article proposes a general structure of hardware MCD system to ensure the required level of reliability and safety of these devices. The proposed structure enables the analysis of reliability assurance of the ATCS devices. The most important achievement presented in the article is to present the possibilities of interdisciplinary integration models reflecting aspects: rail traffic on the approach section, functionality and reliability of railway traffic control devices, which are combined into a single model. The integration of these different models allows for a universal approach to a comprehensive analysis of the entire system, not only in the design phase but also during the operation. In addition, such a process modeling enables its easy expansion with new elements for a variety of critical applications that require simultaneous analysis of functionality, reliability, and safety of operation.

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