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# CONCEPT OF CENTRALIZATION OF CONTROL SYSTEMS FOR LEVEL CROSSING PROTECTION

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## Abstract

In terms of safety, rail-road crossings are critical points of interface between rail and road transport systems. This is due to the fact that among the total number of adverse events that take place in the area of railway infrastructure, the vast majorities are those occurring at these critical points. The issue of the occurrence of adverse events in the area of rail-road crossings has continuously been a serious topic of discussion for all entities related to land transport for many years. There is still a search for innovative methods influencing the improvement of safety at rail-road crossings. The proposed solutions must, on the one hand, take into account many aspects (including: safety, legal, technical) and on the other hand, take into account economic factors.

Currently, there are no crossing systems in Poland that enable the control of multiple remote peripheral devices (barriers, traffic signals, level crossing warning signal) of various rail-road crossings from one control core. The level crossing system enabling remote control from one control core is the PZZ-J system produced by the Czech company AŽD Praha s.r.o. However, this system is not approved in Poland. On the Polish railway network, can often be found a large concentration of rail-road crossings, where installation of such a system would be advisable taking into account economic factors. Reducing the cost of building the system enables the protection of a greater number of rail-road crossings, which implies a significant improvement in safety within these facilities.

This article presents the concept of a control system for multiple remote peripheral devices of rail-road crossings using the PZZ-J system by AŽD Praha s.r.o., in order to group rail-road crossings on a selected railway line managed by PKP Polskie Linie Kolejowe S.A.. The paper also analyzes the mathematical model of a centralized control system for multiple remote peripheral devices of rail-road crossings in order to determine the reliability, availability and safety parameters describing the safety level of the system. Stochastic processes in the form of homogeneous stationary and ergodic Markov processes were used for the mathematical analysis. This method makes it possible to estimate the limit values of the probabilities of failure states and dangerous failures during system operation.

**Keywords:** railway safety, level crossing system, Markov processes, mathematical analysis.

# 1 Introduction

Level crossing (LX) is a crossroads of railway and road which exists in the same level. Special case of such crossing, which is meant to serve only for pedestrian movement is a rail crossing [1]. Both level and rail crossing are a fragile part of the railway infrastructure [2]. On the railway infrastructure in Poland we distinguish 6 categories of level crossings: A, B/C, D, E and F [3]. Each category defines a specific type of the applied safety measures, devices and systems and provides information about controlling of such type of railway object. The use of traffic safety devices at rail-road crossings depends on the adopted category of a level crossing. Systems of traffic safety devices at level crossings can be divided into: active systems (active crossings), passive systems (passive crossings) and safety devices for pedestrian crossings at the rail level [4,5]. At crossings with an active system of traffic safety devices, road users are warned with the use of technical optical and acoustic equipment (permanently installed). Physical protection against unauthorized crossing of the rail-road crossing is performed with the use of barrier devices and traffic signals, controlled mainly with the use of level crossing systems. Passive crossings are not equipped with traffic signals and barrier devices. They are marked with vertical and horizontal signs (depending on local conditions), the purpose of which is to inform and enforce appropriate behaviour of road users [5]. Currently, there are no crossing systems in Poland that enable the control of many external devices (tollbooths, traffic signals, warning discs) of various rail-road intersections from one control core. The cross-over system enabling remote control from one control core is the PZZ-J system produced by the Czech company AŽD Praha s.r.o. However, currently this system is not approved in Poland and is under development process. On the Polish rail network, you can often find a large concentration of rail-road crossings and crossings at the rail level, where the development of such a system would be advisable taking into account economic factors. Reducing the cost of building the system enables the protection of a greater number of rail-road crossings, which implies a significant improvement in safety within these facilities.

The purpose of this article is to present the concept of centralizing the control of rail-road level crossing protection systems using the PZZ-J system developed by AŽD Praha s.r.o.

## 2 Methods

When introducing a new system into the exploitation, it must provide at least the same level of safety as the systems used so far at railway level crossings.

In order to determine the parameters of reliability, availability and safety of the examined centralized system, an analysis was carried out to estimate the basic probabilistic and time indicators describing the safety level of the system. The purpose of the safety analysis determine the basic reliability indicators, which include all probabilistic characteristics such as the average time to the occurrence of a dangerous situation, failure intensity and the probability of that the system is in safe or dangerous state. For this purpose, mathematical models modeling the functional states of operation of the centralized system have been developed in accordance with the guidelines of PN-EN 50126-1, -2 standard.

Modeling the events taking place in the work structure of the examined system and the safety analysis of the centralized system can be described using random processes in the implementation of Markov processes [8,9,10]. The processes taking place in operating rail traffic control systems are typical stochastic processes due to the randomness of events. Therefore, an important factor in assessing the safety level of a centralized system is the analysis of the dangerous failures states, their causes, effects and probabilities of their occurrence during the operation of the level crossing control system working in the centralized structure of system. For this purpose stochastic processes were used in the form of homogeneous, stationary and ergodic Markov processes, modeling the functioning process of centralized level crossing control system.

As part of the research, a reference model was built to describe the standard level crossing protection system using the 2oo2 reliability structure. This structure is currently used in decentralized level crossing systems (i.e. one LX system has its own computers processing dependency logic), and an evaluated model for a centralized structure that supports the operation logic of up to 16 devices located at level crossings (controllers and external devices). This structure uses the duplication of decision computers in the 2oo3 system, which allows maintaining the full functionality and safety of the system. If one of the dependency computers fails, it is not necessary to transfer the control devices to the standby computers mode.

The obtained results of the analyzes in the form of the limit probability of the occurrence of dangerous states defined in the models were compared in relation to the RAMS parameters specified for level crossing systems in order to confirm or reject the adopted concept of level crossing control centralization.

## 3 Results

The LX systems are a collection of devices which, as a whole, perform the function of securing the traffic occurring at the intersection of railway lines (sidings) with roadways. The devices included in the system should be controllable and their design must ensure the control of their efficiency [6]. The PZZ-J level crossing system is a computer (microprocessor-based) system designed for securing rail-road crossings. The described architecture was designed as a centralized control system with remote peripheral external crossing devices using data communication (Ethernet) for control and supervision. Fig. 1 shows the concept of control centralization in the PZZ-J system [7].

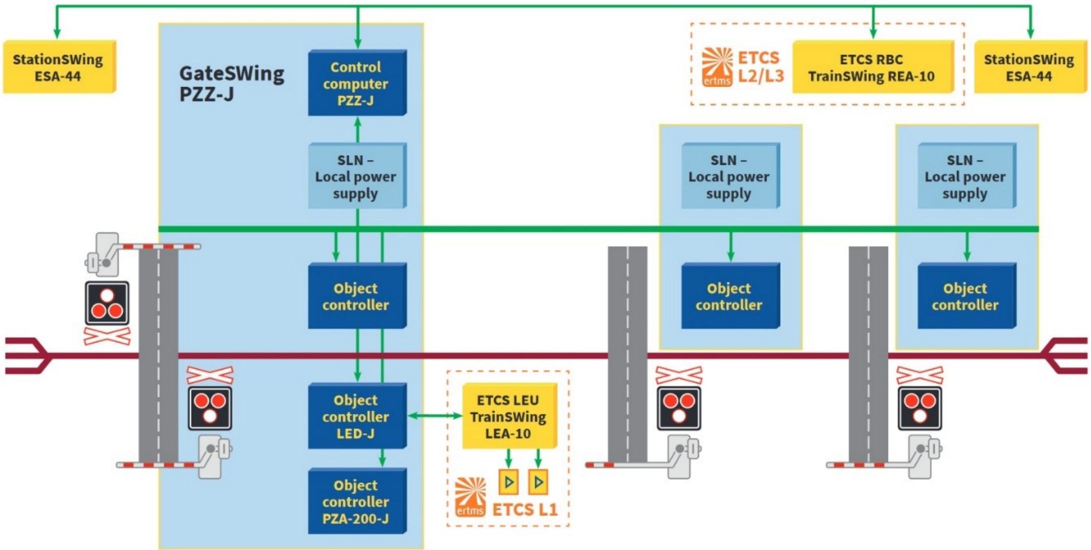


Figure 1: The idea of centralizing the control of traffic safety systems at rail-road crossings in the PZZ-J system [7].

Intelligent peripheral devices (external): the LED-J traffic light and the PZA-200-J barrier drive are individual controllers of objects with their own control. PZZ-J - the control computer (control core) consists of the SPZZ cabinet located in the railway control room or in the cabinet located in the crossing zone. The SPZZ cabinet also consists of a basic control panel with a general SW and implemented functional algorithms, communication technology in standby mode with remote peripherals and centralized PZZ-J diagnostics (for railway crossings). The SLN local power supply cabinet is located at each railway crossing and consists of security elements, power converters, ICT technology and other equipment necessary for the system to function. Field controllers - LED-J traffic lights and PZA-200-J toll gate drives are connected to the SLN cabinet. LED-J creates a remote border with its own control and provides road users with light and acoustic information about the prohibition of entering the crossing area. The PZA-200-J is also a remote peripheral with its own control. PZZ-J The control computer (control core) can control up to 16 railway crossings and 160 intelligent peripheral devices (external devices) (LED-J and PZA-200-J). Compatibility with the ERTMS / ETCS level 2 system is ensured by the interface between the PZZ-J control computer (core) and the setting system or RBC. ETCS level 1 can be connected directly to the PZZ-J control computer (core). The system enables the connection of peripheral devices (external) of various rail-road crossings within a maximum distance of 25 km from the system control core [7].

The purpose of this article is to present the concept of centralizing the control of rail-road level crossing protection systems using the PZZ-J system produced by AŽD Praha s.r.o.

## 4 Conclusions and Contributions

As we described in the introduction part of this paper, level crossings are very fragile and common parts of the railway infrastructure. Since they represent a direct interference into the Right of Way of the railway vehicles, their safety and security remains a vital topic. Due to immense technological progress which allowed emerging of computer based systems in railway environment, new possibilities and solutions present themselves as a improvements from old fashioned localized controlling and managing of the railway infrastructure. Just as distributed interlocking systems for stationary signalling operation, now level crossings are presenting themselves as distributed-operation ready. Presented system of PZZ-J not only allows safe operation and coverage of multiple level crossing with one centralized controlling unit, but also offers intelligent diagnostic system. All that, with reduced infrastructural investments (less trackside objects), smaller environmental impact (lower power consumption) but also cleaner and more green image of the railway (less objects built near railways. The last argument, although seems the least relevant is growing on importance with ambitious goal of the European Union to tackle emission goals in which huge hopes are put in newer, greener railway as an alternative to road vehicles. Distributed, long-distance controlling minimizing the need of trackside objects help to achieve this vision of cleaner railway of the future. From the operational viewpoint, as the results of our analysis have shown newly proposed system is not inferior (in terms of the Level of Service, reliability, safety and accessibility) to classic build on side level crossing systems. All above leads to a conclusion that such remote, distributed systems might be what future railway with densely placed level crossing needs.

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