XXI INTERNATIONAL SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '24
October 10-11, 2024; Niš, Serbia

Original scientific paper DOI: 10.5937/Railcon24083L

TOWARDS A UNIVERSAL COMPUTER BASED LEVEL CROSSING PROTECTION SYSTEM

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Abstract – *This paper deals with the analysis of existing Computer Based Level crossing – CBL-xing protection systems in different countries and for different cases of application. Various types of CBL-xing protection systems are analysed depending on the place of application: in railway stations and on the open track between stations (equipped with an automatic multiple blocks or with ordinary inter-station single block dependence). Numerous functions that depend on the signalling principles and practice in different countries and on the place of application on the track that contribute to the complexity and diversity of these systems have been analysed. Common functions that are necessary for all types of systems and for all applications are recognized and stated. Certain disadvantages of existing solutions in terms of their safety, hardware complexity, time required for design and execution and cost-effectiveness were also recognised. Based on the analysis and knowledge of how the CBL-xing system works, as well as their interfaces with other safety signalling systems, a proposal is made for a universal CBL-xing system a standard system, practically independent of the track layout and country of application. The proposal implies the implementation of the minimum necessary common functionality on the CBL-xing side, while all other necessary functions should be implemented within the appropriate safety signalling devices (like a station interlocking system) with which the CBL-xing is in dependency. The proposed CBL-xing system is an economical solution that also solves many of the above-mentioned disadvantages of existing solutions. Based on the above proposal, company Signalling & Control d.o.o., Belgrade has created one such CBL-xing called ELC (Electronic Level Crossing), which has been applied to the railways of Serbia for ten years.*

Keywords - computer-based level crossing, safety integrity level, electro-relay interlocking, safety analyses.

1. INTRODUCTION

Computer Based Level crossing – **CBL-xing** is a computer-based controlling and monitoring system, which ensures the crossing of the railway and the road. It is realised as modular and scalable - state of the art system for all types of the level crossings (on the single block line, on the line with automatic block and in the station area), for various signalling arrangements and for different railway authorities. CBL-xing usually has the highest safety integrity level (SIL4) in accordance with CENELEC Railway Standards [1].

2. TYPICAL CBL-XING APPLICATION

The typical track layout of a CBL-xing system for a single track application is shown in Figure 1.

CBL-xing contains inside and outside equipment. Inside equipment is realised in the controlling cabinet, which is placed at the hut near the crossing. It contains a power supply and the level crossing controller. Power supply (PS) usually contains two identical parts (PS1 and PS2) for availability. The controller is responsible for the safety of the system. Therefore, its CPU is realised as a 2 out of 2 (2oo2) system (duplicated for safety). Digital inputs and outputs – DIOs serve to connect remaining controlling equipment (flasher, detectors, relays, etc.) with the 2oo2 CPU.

Road related outside equipment is practically independent of the number of tracks and consists of: barriers machines with half booms (BB1 and BB2), road protection signals (RS1, RS2, RS3 and RS4) and warning bells (WB1 and WB2).

Railway related outside equipment is track and traffic direction dependent and for one bi-directional track usually consists of: train protection signals (TPS1 and TPS2), two pairs of switch-on elements

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(11/12 and 21/22) and two pairs of switch-off elements (31/32 and 41/42). Switch-on and switch-off elements and road signals are duplicated for the availability.

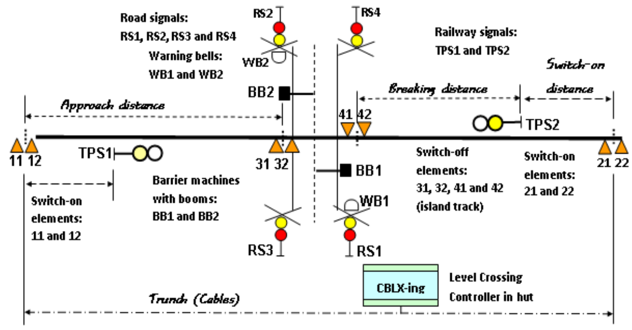

Fig.1. Typical track layout of a CBL-xing system

3. CBL-XING TYPICAL FUNCTIONS

During the long time of application of level crossing protection systems, the automatic half BBs became the most favourable and the most common as it offers an optimal result being a compromise between safety and performance [2].

Some of basic functions realised within CBL-xing protection system are listed below:

- Automatic activation (switching-on) / deactivation (switching-off) by occupation / release of switching-on / switching-off elements;
- Local Operation of Booms - LOB, i.e. activation / deactivation by the locally placed switch or key;
- Activation / deactivation via pushbuttons, with or without registration of use by counters, at signalman office (where applicable);
- Activation (switching-on) is not possible by the leaving train (Directional Stick Function is inbuilt);
- Designable advance warning time for BB and RS flashing lights (usually 15s);
- Designable maximum time of operation (closure) (usually 240s - 480s, typically 300s);
- Maximum time of operation is not applicable during the LOB operation;
- Automatic deactivation (switching-off) of the CBL-xing after maximum time of operation is exceeded;
- Detection of up and down positions and broken state of each BB;
- Designable maximum allowed time for dropping and lifting BB;
- Detection of correct work of the switching-on and switching-off elements;
- Detection of the correct work of the flesher;
- Detection of the protective state (down position of BB, flasher is operational, signal lights are operational and fault is not present);
- Designable time duration of the proceed aspect at the TPS (usually 30s-90s, typically 60s);
- Designable conditions to return the TPS to stop;
- Detection of work of TPS lights;
- Detection of works of RS lights;
- Detection of a Fault (safety critical failure, with registration of numbers by counters)
- Detection of a Disruption (failure with no impact to the safety, for example failure of one of the redundant elements);
- Fault and Disruption are retained until the failure is repaired and local push button is operated;
- Holding down function for the multiple track configurations for the multiple approaching trains;
- Functionality within automatic block or in the station area with the appropriate interfaces.

The Fault is detected in the following cases:

- Brake of a BB;
- One light of a RS is dark;
- Maximum time of the operation is exceeded;
- CBL-xing is not closed within the predefined time after it was switched on;
- One light of a TPS is dark;
- A flasher is not operational or the flashing rate (light / dark ratio) is irregular;
- Irregular operation of switching-on and switching-off elements;
- Irregular operation of BB;
- Battery voltage is below minimum allowed level;
- A 2oo2 CPU does not perform its function, i.e. it is in the stop state;

The Disruption is detected in the following cases:

- A Fault is detected;
- PS from the network (230V AC) is not present;
- One element from the redundant pair is not operational;
- Some time related functions are exceeded but bellow the critical time to detect a fault;
- If one filament is not operational, in the case that classical bulb is used as a signal light.

The Indication Panel (either conventional or computer based) can be placed locally and / or at the remote place to provide the appropriate states of the relevant elements of CBL-xing.

The following indications are provided:

- State of the switching-on / switching-off elements;
- State of the TPS lights;
- State of the RS lights;
- State of BB (up / down positions and broken);
- LOB operation status;
- Regular state (fault and disruptions not detected);
- Disruption state;
- Fault state.

4. COUNTRY SPECIFIC FUNCTIONALITY

Country specific functions depend on the signalling principles and practice in different countries

[3]. Position of a TPS varies and can be related to the service braking distance, emergency braking distance or some other distance related to the signal sighting and a braking distance. For all these cases the TPS clears with the detection of an approaching train. In general there are two main differences, which are related to the operation in the automatic block where an automatic block signal performs function of a TPS, or in the station area where a main signal performs function of TPS:

- English signalling practice:
  - TPS is at stop until the approaching train activates CBL-xing and then clears if CBL-xing is free of faults.
  - Train detection equipment (with time delay relays as needed) of interlocking and blocks uses for switch-on and switch-off functionality.
- German signalling practice:
  - TPS is clear all the time if CBL-xing is free of faults.
  - Additional switch-on and switch-off elements are used for the detection of trains.

There are advantages and disadvantages of both practice, but it is common that the TPS is not an independent signal belonging to the CBL-xing than a signal belonging to the automatic block or to the station interlocking. As a result, complex and application dependent interfaces are required between the CBL-xing and interlocking and blocks. This significantly increases time of realisation and cost of the CBL-xings.

5. PROPOSAL OF A UNIVERSAL CBL-XING

In accordance with the previous considerations, it seems reasonable to propose use of a universal CBL-xing system a standard system, practically independent of the track layout and country of application. The proposal implies the implementation of the minimum necessary common functionality on the CBL-xing side, while all other necessary functions should be implemented within the appropriate safety signalling devices (like a station interlocking system).

The universal CBL-xing system is an independent system and has the following main functions:

- In the station area:
  - Protected by the main signals at stop. Activates by the route setting commands. Deactivates automatically by the switch-off elements.
  - Manual activation and deactivation.
  - Has a standard simple interface with the interlocking, which includes above described commands and indications about the status of the CBL-xing (fault status and BB status, optionally RS status).
- Between the stations:
  - Protected by its own TPS signals at stop, which gives fault free information to the approaching train. Activates and deactivates automatically by the independent switch-on/switch-off elements.
  - Interfaces in general are not required. A train driver will report to the signalman if the TPS indicated faulty state of CBL-xing. The approaching train in this case follows a special procedure that usually includes stopping before the level crossing and slow passage.

The proposed CBL-xing system is an economical system that also solves many of the above-mentioned disadvantages of the existing solutions. Between stations it is completely autonomous without interfaces. In the station areas it has only simple and standard interfaces. Use of the TPS between stations contributes to the higher safety due to the reduced distance (time) between the TPS and level crossing.

Based on the above proposal, company Signalling & Control Ltd, Belgrade has created one such CBL-xing: **ELC** (Electronic Level Crossing), which has been applied to the railways of Serbia for ten years [4].

6. MAIN FEATURES OF THE ELC

ELC is realised as modular and scalable system with possibilities for the applications on various signalling arrangements and for different countries. Typical layout of the ELC controller is shown in Figure 2.

ELC is based on fail-safe **PLC** – *Programmable Logic Controller* of **HIMA** (HIMA Paul Hildebrandt GmbH + Co KG, Germany), which are certified for the highest safety integrity level SIL4 in accordance with CENELEC railway standards [1].

ELC is realised using high degree of modularity. They represent independent highly reliable functional units that are tested and approved for their purpose. Together they form the simple and low-cost hardware structure of the ELC, contributing to the generality, maintainability, higher reliability and safety.

ELC is typically realised for the applications in the extended temperature range from -25ºC to +70 ºC. It is designed for typical enclosure for inside mounting (level crossing hut). Therefore, it does not require additional insulation of the equipment house nor additional heating and cooling equipment. This significantly reduces the power consumption. As a result, the total power supply for the complete (inside and outside) typical ELC solution is under 250W.

Rectifying part of the power supply is realised as a highly reliable single channel structure with battery (long life and maintenance free) backup (minimum 8h), but two pairs of internal and external DC/DC convertors (also highly reliable) are used for the power supply of the internal and external elements.

As a switch-on and switch-off elements practically all known devices for this purpose, such as: electronic rail contacts, inductive while detectors, inductive loops, short range track circuits, long range track circuits, conventional track circuits, axle counters, etc, can be used. It is enough to provide the element state through a voltage free contact. From safety reasons it is sufficient to use single switch-on and switch-off elements, but they can be duplicated for the availability if required.

Fig.2. Controlling cabinet of the ELC system

ELC can use various types of the boom barrier mechanisms, which are approved for use from the relevant railway administrations. It is necessary to provide data about the up and down position and broken state of a boom barrier by the appropriate voltage free contacts. Other relevant functions, including time of lowering and rising of booms are covered by the application software.

ELC supports use of various types of the light modules for RS and TPS, such as conventional bulbs and LED modules (typical use due to the high reliability and low power consumption). The system uses current detection modules with adjustable levels for detection of the current of the LED modules (or main and the auxiliary filaments of classical bulbs).

Electronic flasher is realised as an external, high reliable hardware module with solid-state relays - SSR output with adjustable light and dark phase (typically 50% / 50%). It is continuously monitored by safety PLC. Flasher is realised as a modular and scalable unit and the output SSR are duplicated for the availability.

Minimal necessary number of highly reliable miniature safety relays is used for the interfaces between outside equipment and DIOs of the central PLC system. The conventional safety techniques such as "de-energised state is safe" and back contacts proving are used to insure safety of the interfaces.

The outside equipment is connected to the inside controlling cabinet via lighting (overvoltage) protection modules - LPM, which have disconnection terminals from both sides for easier measuring, and checking and faster testing and commissioning.

The application software is realised by the appropriate functional modules, with designable parameters adjusted to the specific application. During the factory acceptance test - FAT with the realistic simulation of the outside equipment complete functionality is tested. As a result, sight acceptance test - SAT is significantly simplified and practically reduced to test of correspondence of the required elements (commands and status). This contributes to the efficient testing and commissioning.

ELS system is supported by an advanced SD&ER – Service, Diagnostic and Event Recording system. Also with the GSM module, which sends SMS related to the ELC state to the signalman, maintenance staff, dispatcher, etc.

7. CONCLUSION

The ELC is realised as a safety controller of universal type, which covers functionality of an automatic level crossing with half barriers for all types of the track layouts and various types of the outside equipment. It is maintenance friendly. It has very high reliability and very low power consumption.

ELC is also an economical system, highly competitive with both CBL-xing and conventional, relay-based, level crossing protection systems.

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