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COMPARATIVE ANALYSIS OF THE FUNCTIONALITY OF CENTRALIZED AND DISTRIBUTED LEU

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Summary – This article addresses the centralized LEU (Lineside Electronic Unit) encoder used in ERTMS/ETCS Level 1 (European Rail Traffic Management System / European Train Control System). It is explained what a centralized LEU encoder is and why this solution offers more possibilities than a distributed approach. Also explained the general principle of the encoder and how it works with switchable Eurobalise. The paper also juxtaposes how it works with and connects to the interlocking system in both the distributed and centralized approaches. The differences between the centralized and decentralized LEU encoder in diagnostic and management capabilities are also described.

Keywords – ERTMS, ETCS, LEU encoder, Eurobalise

INTRODUCTION

Railway systems developed in many parts of the world simultaneously and often completely independently, and as a result they can differ significantly from each other, depending on the country or region in which they were established. In the early days, most connections were local often within a particular region or country, while international ones were just emerging and made up a small percentage. However, with economic development and increasing frequency of travel between countries, the demand for such relations increased. A problem then arose because train travel between countries with different train control systems required the installation of many such systems on the vehicle. Moreover, the driver had to know how to operate each of them. Today, the number of on-board systems needed for the control subsystem on a single route can reach up to 7 [1].

There are dozens of different control systems in Europe. In order to reduce the cost of equipping vehicles and unify railroad systems in Europe, a consortium of companies called UNISIG came together with the goal of creating an international standard called ERTMS (European Rail Traffic Management System), consisting of the ETCS (European Train Control System) traffic management system and the GSM-R (Global System for Mobile Communication for Railways) track-to-vehicle communication system. The consortium of companies that formed ERTMS included ADTRANZ, ALCATEL, AL- STOM, ANSALDO SIGNAL, INVENSYS RAIL, and SIEMENS. This system, has not only become a European standard, but also in the world it is widely used. As much as 35% of lines equipped with ERTMS are located in Asia.

China has developed its own system called CTCS (China Train Control System), which is based on the assumptions of ERTMS [2].

Even before the emergence of an international standard such as ERTMS, manufacturers of national systems were using cab signaling in their solutions. Examples of such systems are the German LZB (German: Linienzugbeeinflussung) or Bombardier's EBICAB, used mainly in Sweden and Norway. EBICAB was planned to be implemented in Poland, but was abandoned in favor of the ERTMS/ETCS system, whose imminent implementation prospects offered greater benefits [3]. The first experimental system, supporting cab signaling, was tested in the UK in the first decade of the twentieth century [4]. Their multiplicity also contributed to the need for standardization in the European market, since with several national systems installed on a vehicle, where some had cab signaling, it was necessary to place each system so that the driver could observe it. Which undoubtedly decreases the driver's comfort and causes an increased risk of confusion as to which cab signaling should be used at which location.

ETCS, also known as Class A system, provides an increased level of safety com- pared to Class B systems (national systems). In addition, it includes cab signaling that gives the driver continuous information, about the traffic situation in front of the train and, above all, increases the level of safety. Digital track-to-vehicle communications are implemented in two standards as point-to-point unidirectional (Eurobalises, Euroloops) or bidirectional and continuous (GSM-R radio). The implementation of ERTMS/ETCS is a key future-oriented element for Polish railways, giving the opportunity to increase the speed of trains, because according to the PKP instructions, without ERTMS/ETCS, trains can only run at speeds not exceeding 160 km/h [5].

Another component of the ERTMS system is the GSM-R communications network, which is a special variant of GSM cellular communications for railways. It is used for ETCS data exchange and to provide voice communication with the driver.

In the ERTMS/ETCS Level 1 system, the primary means of communication be- tween the vehicle and the Interlocking are Eurobalises, which come in two varieties: non-switchable (fixed) Eurobalises and switchable Eurobalises also called programmable (transparent) Eurobalises. Non-switchable Eurobalises are used in all levels of the ETCS system. They transmit fixed-invariant information to the vehicle, such as the number of a group of balises, the longitudinal profile of a section, a message announcing the next group of balises (linking), or a set of national values (National Values). However, they are unable to transmit time-varying information that depends on the traffic situation. For this purpose, switchable Eurobalises are used, which receive a variable telegram from a LEU (Lineside Electronic Unit) encoder that tracks the behavior of the dependency system by viewing the state of its outputs (usually the state of the light bulbs on the signals).

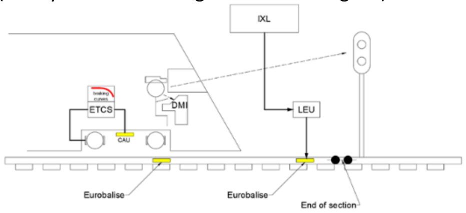

Fig. 1: Diagram of the operation of level one of the ERTMS/ETCS system

I. LEU ENCODER WORKING PRINCIPLE

The LEU encoder of the classic variety reads the status of the executive devices of the dependency system, i.e. signals, crossing warning signals, shunting signals and sometimes switches. The classic LEU encoder consists of the following components:

- LEU encoder card implementing C1, C6 and C4 interfaces

- Analog input cards for reading the status of light bulbs on signals

- Binary input cards for reading, for example, the position of points

- Rack, power supply and other necessary accessories.

There are usually many such sets at a station or line.

The main task of the LEU encoder is, based on the identified state of the devices, to select a telegram from the decision table and then, via the C1/C6 interface, transmit the selected telegram to the switchable Eurobalise [6]. The Eurobalise is energized with telepowering (interface A4) from an antenna located on the vehicle, then sends this telegram to the passing train via interface A1. It is worth noting that the LEU encoder reads the status of only one signal device and, auxiliary, for example, the status of switches (this functionality is very rarely used). Therefore, an individual telegram is designed for each signal state, which is then entered into the decision table of the LEU encoder, taking into account all safety rules. Thus prepared, the LEU is already ready for operation.

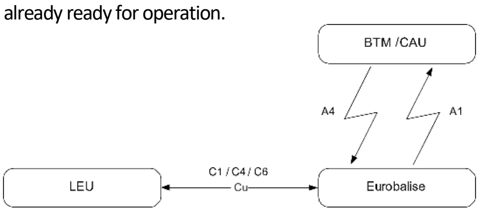

Fig. 2: Data exchange interfaces between LEU and Eurobalise [7].

During changing states of Interlocking devices, the transmitted telegram changes. In order to make it easier for the vehicle devices to detect a change in the telegram, a short series of zeros is transmitted by the LEU. In addition, there is an optional C4 interface in the LEU encoder, through which information about the train over the Eurobalise is transmitted from it to the LEU. This information can be used by the LEU to delay the telegram change so that it does not go under the train (this delay is, of course, time-limited).

II. WHAT DOES LEU CENTRALIZED MEAN

The distributed approach provides variability of the transmitted information depending on the state of the dependent devices and a large amount of cabling, however, such a solution is not very flexible. It is possible to make the telegram dependent only on the state of one device, possible dependency with more devices is very costly, as it requires routing cables between all these devices.

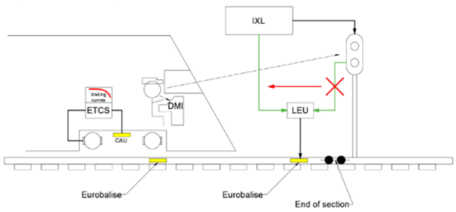

Fig. 3: Schematic of the level one operation of the ERTMS/ETCS system using a centralized LEU.

Centralized LEU, is an LEU encoder devoid of analog inputs and binary cards. These are replaced by an electronic interface that takes data directly from the Interlocking system. Thanks to the integration of LEU encoder logic with data from the Interlocking system, and thanks to the lack of restrictions on the amount of transmitted data, the decision tables of LEU encoder logic can be made very flexible. The transmitted telegram to a switchable Eurobalise can be made dependent on the set route or group of routes, instead of on the state of the lights of a single signal. Such a solution gives much more configuration possibilities and improves traffic flow.

The centralized LEU consists of the following components:

- central logic working with Interlocking (one per station)
- LEU encoder card implementing C1, C6 and C4 interfaces (many at the station)
- Rack, power supply and other necessary accessories.

The main problem of the distributed approach is the situation when the same signal image is displayed for two different routes, and this is especially troublesome when the two routes differ significantly in length. In the transmitted telegram form the Eurobalise, there should be information announcing the next group of Eurobalises (the so-called linking), while for the two routes above, these groups have a different name and are at different distances from the linking Eurobalise. In this case you need to use additional Eurobalise groups for update. For a centralized LEU, this is not a problem at all, since, as previously mentioned, the telegram can be dependent to route instead of signal.

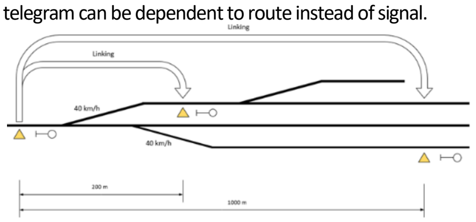

Fig. 4: An example of the situation when two different Eurobalises can be linked for the same indication of the beacon.

An additional functionality enabled by this approach is the dynamic introduction of Temporary Speed Restrictions from the Interlock. This is possible, of course, at predefined locations and only in areas where at least baseline 3 is in effect [8]. It enables the transmission of a telegram with package number 0: Virtual Balise Cover (Subset 026 Chapter 7 "ERTMS/ETCS language" subsection 7.4.2.0) [9], which informs the on-board system that it should disregard the information contained in this Eurobalise.

The next extension of functionality is the ability to adapt LEU encoder configurations to non-stop runs. In the classical approach, this is possible, but it additionally requires reading the state of the upper signal lights, which further increases the cost of installation [10]. This extension of functionality makes the ERTMS/ETCS Level 1 system functionally similar to Level 2, at a much lower cost [11]. However, due to point-to-point track-to-vehicle transmission, it is unable to achieve equally good throughput. It does not require the installation of a wireless track-to-vehicle communication system – GSM-R -version for L2 in the system area.

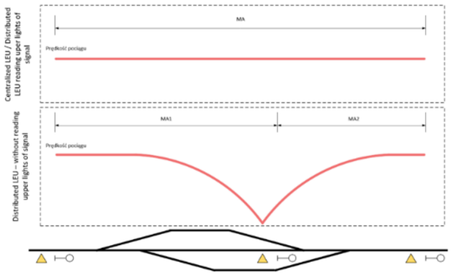

Fig. 5: Train speed differential for non-stop runs

III. Diagnostics and management

Nowadays, diagnostics of LEU devices is becoming increasingly important, and by following the tenders it can be seen that PKP PLK is also beginning to recognize this need. In the conventional approach, in order to ensure the diagnostics of LEU encoders, it is necessary to periodically check their condition by employed engineers at the station or build additional expensive diagnostic devices. These devices reread the status of signals read by LEUs and the telegrams they generate, resulting in, longer detection time for possible faults, or the possibility of generating false fault alarms when the diagnostic device fails. In the centralized approach, diagnostic data are easily accessible from the data source for the LEU, i.e. from the Interlock. The diagnostic system and the LEU get the same data at the same time, which makes the accuracy of diagnostic decisions much higher. The diagnostic software can inform the operator about possible faults, practically at the moment of its occurrence, and the cost of such diagnostics is much lower.

IV. Conclusions

The LEU encoder is a safety-critical component of the srk system. The classic- distributed encoder provides greater versatility of the solution and complete independence from the type - manufacturer of the dependency system. However, centralization provides greater flexibility and, above all, system diagnostics.

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