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Propaedeutic of the methodology of improving electromagnetic compatibility of railway traffic control systems in relation to the implementation of the EMC4CCS – BRIK project

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The purpose of this article is to introduce to the methodology of increasing electromagnetic compatibility in distributed system, on the example of the implementation of works in the field: "Research and improvement of electromagnetic compatibility of railway traffic control devices and rolling stock", which are the subject of the BRIK project. The methodology is defined here as a set of rules for conducting research in order to achieve an intended goal. The article proposes a procedure to improve the EMC condition of distributed systems. For monitoring the quality of the system operation in terms of electromagnetic compatibility, the implementation of the OEE indicator was suggested.

1. Introduction

The definition of the railway infrastructure as a distributed system is included in the definition of a system, understood as a set of autonomous technical components connected in such a way that the user has the impression of using a single system [1]. In extensive railway structures, this is what is intended to be preserved. An example is Centralized Traffic Control (CTC), a railroad signaling system that operates in North America, which combines train route mapping decisions that were previously carried out by local signaling operators. One of the elements influencing the achievement of such an assumption is the interoperability of the system – its ability to ensure the safe and uninterrupted movement of trains. Directive (EU) 2016/797 of the European Parliament and of the Council [3] provides guidelines and constituting essential requirements, including electromagnetic compatibility between the devices of the system, as well as the system and its operating environment. By meeting these requirements, the expected compliance can be achieved. It is a factor that causes that the risk of loss of functionality of a distributed system is at the ALARP level – *as low as reasonably practicable*. To keep them in the changing environmental conditions and quality requirements of the user and functions, technical procedures are necessary, an example of which, in the field of electromagnetic compatibility, is the project BRIK – research and development in railway infrastructure [2].

The research and organizational experience and practices applied during the implementation of the BRIK project prompted the team of authors of this article to prepare a proposal for a universal methodology for improving electromagnetic compatibility. It no longer applies to a single device – for example an axle counter, not only to an installation – for example a railroad crossing. It concerns systems that are interconnected in an interoperable structure.

Detailed results of the BRIK project are available through the entities that ordered its implementation – NCBR and PKP [2]. Their discussion is the subject of prepared separate publications.

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The methodology of increasing the EMC (Electromagnetic Compatibility) level, according to which the BRIK project was implemented, described in chapter 2.1, is linear, with the result included in the last stage of the process. The proposed new methodology with a performance indicator, described in chapter 2.2, has a solution based on the principle of internal feedback.

2. Methodology

2.1. Methodology according to the BRIK project

The aim of the BRIK project was to develop technical guidelines for the creation of a working environment for railway traffic control devices that are particularly exposed to disturbances from modern rolling stock in the form of electromagnetic fields with a wide frequency spectrum. Based on the research and analyzes, technical criteria were proposed in three aspects: emission limits for disturbances generated by railway equipment, immunity levels for these devices, and methods of shielding and limiting the interactions of disturbances propagated by on-board equipment of rolling stock and track-side equipment. The results of the technical tests carried out were compared with the existing environmental conditions and the applicable normative documents. The project consisted of several stages:

1. Environmental interview and polling, in order to determine the broadest possible spectrum of problems in the operation of devices that may have a genesis in the case of incompatibility between trackside devices and rolling stock devices.
2. *In-situ* tests and laboratory tests were carried out based on the interview data in order to determine the model of disturbances from the rolling stock.
3. Analysis of the obtained test results in the context of the applicable standards listed in the mandatory regulations.
4. Testing the sensitivity of devices with the use of a designated model, susceptible to disturbances from the operating environment.
5. Specification of relevant technical guidelines having for improving the compatibility between traffic control equipment and rolling stock.

Regarding point 1 – the implementation of this stage of the process consisted in collecting data by means of questionnaires and conducting interviews combined with an on-site inspection in places of railway infrastructure where there were incidents indicating the lack of electromagnetic compatibility. The milestone of this stage is the classification of the probable cases of electromagnetic incompatibility between the rolling stock and railway traffic control devices and the selection of sites for field tests and recommending types of devices for laboratory tests.

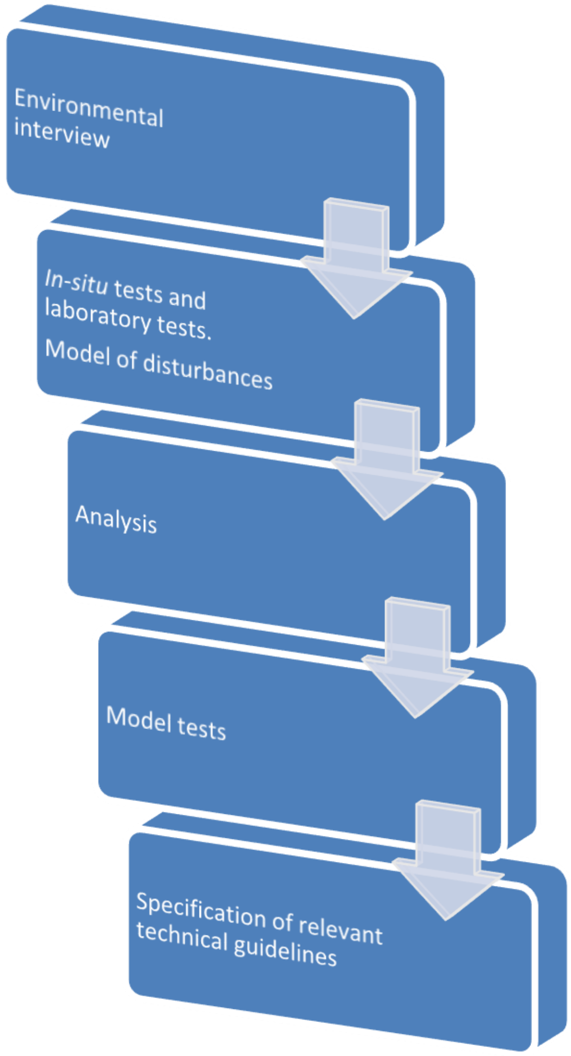

Fig. 1. The process of improving electromagnetic compatibility of distributed system according to the BRIK project

2.2. Methodology with an efficiency index

Using the methodology proven in the BRIK project – understood as a set of principles concerning the methods of improving the electromagnetic compatibility of the railway network, this article proposes a generalization that can be applied to all distributed systems. A significant change in the procedure of this method is the addition of an indicator monitoring the quality level of the system's operation that generates appropriate scenarios of operations.

The catalog of solutions used for local systems, mainly manufacturing systems, includes the Overall Equipment Effectiveness (OEE) [5] indicator, which can be implemented in the proposed solution.

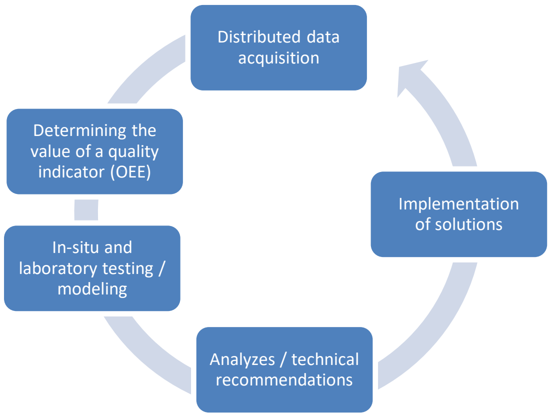

Fig. 2. General diagram of the proposed EMC improvement procedure in distributed systems

Overall Equipment Effectiveness is the gold standard for measuring productivity. OEE is the single best metric for identifying losses, benchmarking progress, and improving the quality.

By measuring OEE and base losses, you can gain important information on how to systematically improve your production process.

OEE is calculated as the product of its three constituent factors:

OEE [%] = Availability × Performance × Quality

- Availability score of 100% means the process is always running during Planned Time. In particular, availability is degraded by failure states
- Performance takes into account Slow Cycles and Small Stops. A Performance score of 100% means when the process is running it is running as fast as possible.
- Quality takes into account defective products/ services. A Quality Score of 100% means no defects.

In order to calculate the OEE indicator, it is necessary to collect data, process it, and then prepare the results in a useful form.

These processes can be carried out using the "paper" method, the method manually supported by software, but also the Manufacturing Execution System (MES) or the OEE calculator [4, 5].

There is a tendency to replace the manual form of recording and calculating performance coefficients, including OEE, in favor of the use of specialized IT systems, thanks to which it is possible to monitor the effectiveness of processes in real time and their reporting for any period and in any context [6].

Selected categories proposed by the concept of "Six Big Losses" [7] can be used to analyze the EMC state of an interoperable system. It is consistent with the idea of determining the OEE indicator and may be the target of activities aimed at improving the quality, reliability and efficiency of distributed railway systems.

Examples of detectable and monitorable loss factors for EMC:

- Availability Loss: Setup and Adjustments, Breakdowns – e.g. downtime resulting from a failure caused by loss of immunity to SURGE, EFT or ESD disturbances;
- Performance Loss: Reduced Speed, Small Stops – e.g. operation of automatic locks in systems with axle counters under the influence of magnetic fields from rolling stock, in situations that do not require intervention;
- Quality Loss: Production Rejects, Startup Rejects – e.g. emerging interference in radio transmissions due to incorrect installation of power supply systems.

3. Conclusions

Electromagnetic compatibility not only between devices but also between installations and, as shown by the implementation of the BRIK project – in the railway infrastructure, is of great importance for the quality and functional safety of a distributed system. As shown in the article, by using real-time monitoring of the system performance index – you can get a tool to achieve higher quality of services or products. The aspect of electromagnetic compatibility, as a factor influencing the quality of organizational and technical solutions, should be taken into account by designers of distributed systems.

Nomenclature

CTC Centralized Traffic Control
EFF Electrical Fast Transients
EMC Electromagnetic Compatibility
ESD Electrostatic Discharge
OEE Overall Equipment Effectiveness
MES Manufacturing Execution System
SURGE high energy disturbance

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