UDK 656.259.1

R. BOTNAREVSCAIA –Railway of Moldova, rodicanaspeac@gmail.com
T. SERDIUK – Associate Professor, Dnipro National University of Railway Transport named after academician V. Lazaryan, Ukraine, serducheckt@gmail.com,
ORCID: 0000-0002-2609-4071

ANALYSIS OF OPERATION OF RAILWAY COMMUNICATION SYSTEMS

Introduction

Economic and technical progress worldwide opens up new horizons for technical re-equipment and large-scale implementation of electronic equipment in various areas of our lives. Electronic equipment is widely introduced on the railways of Ukraine. This is where the main question of the compatibility of the types of electric traction used at the Ukrzalyaznytsia enterprise and its electromagnetic effect on electromagnetic influence on the operating electronic equipment used in communication lines.

In Eastern Europe, communication systems on the railroad were built in approximately the same way: cable communication lines (CCL) and overhead communication lines (OCL) and radio communications. Cable communication lines in a metal sheath combined with plastic sheaths protect cable chains from external electromagnetic influences created by traction currents of electrified railways, power lines, and other sources. CCL between large nodes, the connection is laid by a trunk cable and sealing equipment on both sides of the K-60p. The equipment of the K-60p system is developed on semiconductor devices in the 12/252 kHz spectrum and provides 60 channels of tone frequency (with a transmitted frequency band in each channel from 300 to 3400 Hz). Levels for transmission -1.5 Np, for receiving +0.5 Np at a test frequency of 800 Hz [1 - 9].

The peak of the mass introduction of this equipment fell on the 70-80 years, and it was advanced at that time. Despite the fact that all the service life of this equipment has passed in terms of the safety factor, the K-60 continues to operate to this day. The modernization and replacement of the communication system is very slow and there is a temporary imbalance between the old communication equipment and the emergence of new locomotives, new modern control systems for railway processes, and the question arises about the electromagnetic compatibility of old equipment and new sources of electromagnetic radiation. So, the scientific work deals with the analysis of operation of railway communication systems are actuality.

The object of research is railway communication lines.

The main purpose is to evaluate the quality of different kinds of railway communication and the reasons of noise and interference in these systems.

It is needed to carry out the follows steps to achieve these goals:

- to analysis the reasons of appearance noises in the telecommunication channels (radio and wire communications);
- to evaluate the main faults in the overhead communication lines and their influence on the quality of communication;
- to research the electromagnetic interferences in the communication lines and their frequency diapasons;
- to plan further ways of investigation and simulation of influence traction and non-traction systems on the communication channels.

Appearance of noise in the communication channels

One of the disadvantages of this system during the operation was the appearance of crosstalk between the system's channels, which can increase the nonlinear distortion in the channel. Depending on the magnitude and nature of the interference caused by parasitic components of one type or another, the degree of their suppression is about 55-60 dB [1, 4-6, 11-14].

Such a situation can lead to a misunderstanding of what has been said and can lead to severe violations in train traffic safety.

Long-term lack of funding for significant repairs of trunk cables leads to the possibility of only «patching» the cable, replacing heavily damaged sections with cable inserts, and the appearance of a large number of couplings on the cable, which in itself deteriorates the quality of communication. Over time, the couplings themselves can lose their insulating qualities and, with an increase in soil moisture, leads to the appearance of «transient» noise when information from another channel is listened to in the communication channel. Also, in the «locked» cable, the operation of the transmitter relay from the automation devices can be monitored when the train passes, along the track circuit, near the point of deterioration of the insulation in the cable. The most unpleasant moment for such a cable can be damaging insulators on high-voltage transmission lines. Leakage currents and short-circuits to the ground lead to severe crackling and noise in the communication channel. With such interference, it is almost impossible to understand the transmitted information and makes it unbearable to be near the loudspeaker of the train dispatcher's communication console for a long time.

Overhead communication line

In the Post-Soviet Era, there are still sections with overhead communication lines (OCL), some of them use two-wire systems (V-3, VS-3; V-3-3, V-Z-Zs OV-3-3 and OV-12-3). These systems operate as two- and three-channel two-wire transmission systems covering a frequency range of 4 to 31 kHz [1, 4-6, 14 - 15].

The «enemy» of this system is the bad weather condition: the wind leads to the intertwining of the overhead lines, falling branches from near growing trees and icing - to the breakage of communication lines. Cases of theft of VLS by the population have become more frequent against the background of general impoverishment. External sources of electromagnetic interference which can be damaging the quality of communication: switching, short circuits in high, medium, low voltage networks; external, internal sources of radiofrequency radiation; discharges of static electricity; lightning strikes; sources of conducted noise on power supply circuits; electromagnetic radiation from various sources of industrial enterprises. At the final point of communication, as a result, they are heard in the form of strong crackling, noise and lead to a misunderstanding of the transmitted information between subscribers.

Radio communication

One of the most vulnerable and dangerous places of influence of electromagnetic fields of high-voltage communication lines and traction rolling stock is radio communication. Let us consider the problem using the example of a train dispatcher radio communication (DSC) – a station attendant – a locomotive (driver). This type of communication is organized according to the following points:

- Stationary radio communication console at the train dispatcher.
- Radio communication equipment.
- Compaction equipment in LAZ.
- Trunk communication cable.
- Introductory station equipment.
- Antenna transmitting device at the station.
- Ether.

- Antenna transmitting device in the locomotive.
- Radio station in the locomotive [3-5, 7-9].

Such a combined scheme allows the DNTs to communicate with the driver of any locomotive located on its site.

To organize train radio communication, the hectometer range (HF) is more often used: frequencies of 2.13 MHz (channel I) and 2.15 MHz (channel II). Radio interference levels in the hectometer range are high, therefore, for a good quality radio communication, a high level of radio signals must be provided at the input of radio station receivers. To reduce the level of interference and increase the level of the radio signal in the hectometer range, guide lines are used - waveguides suspended on the supports of the contact network or wires of power supply lines and overhead communication lines running along the railway. But all the classical protection measures for devices are not ideal, and the quality of radio communication continues to suffer from electromagnetic influences (EMI), for example, when current collection is disturbed. As a result of the research, it is necessary to develop technical measures to ensure the electromagnetic compatibility (EMC) of train radio communication systems. When carrying out work, it is necessary to take into account the speed of train movement, weather conditions, and also analyze the main factors that arise when the current collection is disturbed. It is planned to develop a mathematical model for the investigation of electromagnetic influence of traction and non-traction power supply systems on the railway communication channels and systems in the different modes of their work.

Electromagnetic interferences in the communication lines

The most problematic of these EM interferences are the low frequency magnetic fields created by the currents (including the earth leakage currents) on the high voltage power distribution system. To analyze the magnetic fields, a 3D simulation of vehicle geometry needs to be carried out.

Generally, for definition the electromagnetic interference (EMI) in the traction supply railway system two main types can be considered: alternative current (AC) systems and direct current (DC) traction systems. There are two current standards for electrified railways on the Ukrainian railway: direct current with a voltage of 3.0 kV and alternating current with a voltage of 25 kV and an industrial frequency of 50 Hz. The fundamental part of the AC traction system causing the EMI is the overhead contact system (OCS) [2, 5, 6, 8]. This system is a source for electric trains and is located above the track. In this case, the rails and ground serve as return circuits. Therefore, if the feeding and return conductors are not symmetrical with respect to the ground or locomotive's pantograph has a bad contact with OCS, it can be a source of EMI. However, optimization of the system allows decreasing the electromagnetic radiation. But issue connecting with noise generated in the communication lines does not disappear.

The DC traction systems' interference is caused by existing high voltage and currents between the running rails and ground. This traction current generates a significant electromagnetic field that could cause corrosion in different structures. Furthermore, it could interfere in the communication lines and in the sensitive equipment near plants, hospitals, and universities.

Nevertheless, it is important to consider not only the internal systems but also the external EMI sources. If the train is defined as a black-box system, including communication, power and signal lines, and On-board Train Control Systems in the modern locomotives, we must gauge and estimate the EMI from the environment. Such interference can be separated into several categories. First of all, it is artificial radiators that do not connect with the railway. There are a lot of cell towers and television antennas throughout the railways. On the other hand are natural EMI sources, for example, lighting and other electrostatic discharges or intense solar magnetic storms. Natural sources usually don't produce high-frequency radiations, but there are exceptions.

The main source of EMI in electrified traction is harmonics originated from traction transformers, traction converters, electrical motors, pantograph arcing etc. Traction converters play a vital role in electric traction systems as high power energy flow control devices. Nevertheless, the rapidly changing voltage frequency, required by the working process might cause a strong electromagnetic emission effect. AC motors are considered to be the cheapest and effective solution for a wide range of electric traction (ET). Working with the converter's high-frequency power supply it becomes an EM transponder, making it barely impossible to provide feedback information required by the control system, especially at the compact interior of the ET. The EMIs generated by traction converters include high frequency harmonic noise caused by PWM control, surges in the current and the voltage caused by switching process, etc. The strong EMIs will interfere with the communication system and control system and affect the vehicles' safety. Therefore, these EMIs should be limited to meet EMC standards. The principal challenge in this case is having the opportunity to predict possible future events with EMI and to forecast the consequences. This knowledge will allow to us develop re-equipment means and techniques to prevent failures.

Role of simulation

The 3D model would help identify and track magnetic field intensity over the ET's structure. The simulations could be verified using multiple magnetic sensors such as Bartington fluxgate and field probes at different positions of the structure. The experimental setup described in radiated current measurement tests of standards such as CISPR 12 and CISPR 22 can be used for magnetic field scanning. These measurements, however, are not straightforward as the fields are time varying and broadband, moreover these standards only envision conventional combustion engines and mechanical counterparts for the emission tests, which only produces static fields. Therefore, the measurements need to be strengthened mathematically and methods like inverse Fourier transform needs to be explored to investigate the fields spatially. A detailed analysis of spatial properties of the fields, along with the vehicle's structure and materials properties are required to recommend mitigation techniques.

Proposed method concludes in the follows.

This study outlines the methods of measuring magnetic fields in ET and their significance with relevance to EMC. A survey of previous studies relevant to the topic will also be carried out with discussions on the advancement of measurement techniques.

To analyze the processes of electromagnetic influence on cable and overhead communication lines, it is proposed to use a mathematical model, in which the experimental section of the communication line will be presented as an eight-pole. Such a representation of the circuit takes into account the influence of various noise sources and the influence of external factors leading to a change in parameters and affecting the operation of related devices of electric rolling stock, railway automation and industrial leaks. For the specified model, you can write a system of differential equations. Moreover, the above system of differential equations can be solved as an equation of the mass-spring system. And also for making a final decision and summing up - compare the results.

Regarding the purpose of our research and taking measures to reduce electromagnetic crosstalk and other types of interference associated with changing the normal operation of digital devices, I would like to propose the following plan:

- Search and analysis of the operation of equipment for measuring the electromagnetic influence of external sources on digital equipment, as well as analysis of the compatibility of the equipment in terms of electrical parameters with the existing communication systems on the railway network in Ukraine.

- Development of measurement methods.
- Interfacing of measurement equipment with existing digital systems on the railway network in Ukraine and methods of reflecting the measurement results on a computer.
- Development of a plan, timing of measurements.
- Coordination with the management of the Signaling and Communication Service of Ukrzalyaznytsia of the time, conditions and requirements for carrying out measurements.
- Measure the parameters of digital equipment in ideal conditions (in the absence of the influence of external sources of interference).
- Measure parameters under the influence of external sources of interference.
- Registration of statistics and measurement results.
- Summarizing.
- Development of a system and methods for multichannel measurements in the time domain to assess the problems of electromagnetic compatibility in railway transport.

Conclusions

The reasons of appearance noises in the telecommunication channels (radio and wire communications) were analyzed.

The main faults in the overhead communication lines and their influence on the quality of communication were evaluated.

The electromagnetic interferences in the communication lines and their frequency diapasons were researched.

The further ways of investigation and simulation of influence traction and non-traction systems on the communication channels were described.

The novelty is in the proposition of use CST simulation to investigate electromagnetic influence of traction and non-traction power system on the communication channels with the 8-poles mathematic modeling.

Electromagnetic effects can manifest themselves in the form of reversible and irreversible disturbances. So, noise during a telephone conversation can be called a reversible violation. Irreversible violations include a failure in the operation of the relay protection system, which led to the disconnection of the load.

References

1. Vinogradov, V.V. Lines of railway automation, telemechanics and communications / V.V. Vinogradov, S.E. Kusteshev. - Moscow: Transport, 2002. - 433 pp.
2. Rules for the implementation of electricity. SD-0055: Approved: Order of the Ministry of Transport and Communications of Ukraine 23.11.04. No. 1026 / Min-in transport. and communications of Ukraine – 2005 .– 181 pp.
3. Complex of radio monitoring AVK ORION. Manual. DUU 1.200.000 NO
4. Vinogradov V.V., Kotov V.K., Nuprik V.E. Fiber-optic communication lines: a textbook for technical schools and colleges of the railway. / V. V. Vinogradov, V. K. Kotov, V. E. Nuprik. Moscow: Zheldorizdat. – 2002 – 278 pp.
5. Sapozhnikov, Vl. V. Power supply of railway automation, telemechanics and communication devices / Vl. V.Sapozhnikov, N. P. Kovalev, V. A.Konoyov, A. M. Kostromirov, B. S. Sergeev. - Moscow: Route. –2005. -453 pp.
6. Mikhailov, A. F. Power supply devices and linear structures of automation, telemechanics and communication of railway transport / A. F. Mikhailov, L. A. Fretedov – Moscow: Transport, 1987.– 383 pp.
7. Akbashev, B. B. Protection of telecommunication objects from electromagnetic actions / B. B. Akbashev, N. V. Balyuk,

L. N. Kechie - Moscow: Griffin, 2013 – 472 pp.

8. Gorelov, V.G. The theory of signal transmission in railway transport / V. G. Gorelov. Moscow –1999. – 416 p.
9. Volkov, A. A. Radio transmitting devices / A. A. Volkov– Moscow: 2002. – 352 pp.
10. Technologies and means of communication. - No. 6. – 1999.
11. Semyon, A. B. Structured cabling systems/ A. B. Semyon, S. K. Strizhakov I. R. Suncheley – Moscow: 1999.
12. Lebedinsky, A. K. Telephone switching systems / A.K. Lebedinsky. Moscow. – 2003. – 496 pp.
13. Kozlov, L.N. Lines of automation, telemechanics and communication in railway transport / L. N. Kozlov, V. I. Kuzmin. Moscow: Transport. – 1981. – 232 pp.
14. Grodnev, I. I. Linear communication facilities / I. I. Grodnev, N. D. Kurbatov Moscow: Communication, 1978. –296 pp.
15. Rules for the protection of wired communication devices from the impact of the traction network of direct current electric railways. Part I, Moscow: Transport, 1969. – 44 pp.

Ключові слова: система тягового електропостачання, лінії зв’язку, експериментальні дослідження, гармонічні перешкоди, електромагнітна сумісність.

Ключевые слова: система тягового электроснабжения, линии связи, экспериментальные исследования, гармонические помехи, электромагнитная совместимость.

Keywords: traction power supply system, communication lines, experimental research, harmonic interference, electromagnetic compatibility.

Рецензенти:
д.т.н., проф. А. Б. Бойнік,
д.т.н., проф. А. М. Муха.

Надійшла до редколегії 15.09.2019 р.
Прийнята до друку 30.09.2019 р.