SELECTED ABSTRACTS OF PH.D. THESES SUBMITTED AT RUSSIAN TRANSPORT UNIVERSITIES

The texts of the abstracts originally written in Russian are published in the first part of the issue.

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Glyzin, I. I. Improving the energy efficiency of traction electric drives with static electricity converters and asynchronous traction motors. Abstract of Ph.D. (Eng) thesis [*Povyshenie energoeffektivnosti tyagovykh elektroprivodov so staticheskimi preobrazovatelyami elektroenergii i asinkhronnymi tyagovymi dvigatelyami. Avtoref. dis… kand. tekh. nauk*]. Moscow, RUT publ., 2022, 18 p.

Russian railways are the second largest transport system in the world. The length of electrified railways in Russia is more than 43 thousand km. «Program for electrification of railway sections of the network of JSC Russian Railways for the period up to 2050» the electrification of sections of railways with alternating current is envisaged, as well as the transfer from direct to alternating current of several sections of railways, which determines the demand for electric rolling stock (ERS) of alternating current on the railway network.

One of the priority areas for development of ERS is to increase energy efficiency and, as a result, reduce the cost of the life cycle of ERS.

On the AC ERS, the conversion of electrical energy coming from the contact network to the traction motors is conducted by a converter system consisting of a traction transformer and a valve converter. The converter system of mass-produced AC electric locomotives consists of a traction transformer and a reversible converter (RCC).

The traction electric drive of a modern AC electric locomotive consists of a converter system, which includes a traction transformer, a semiconductor power converter and asynchronous traction motors. At the same time, the most important task is to create control methods and algorithms that provide the required traction and energy performance and electromagnetic compatibility of the electric locomotive with the infrastructure under conditions of changing parameters of the traction power supply system.

The objective of the work was to increase the energy efficiency of AC electric locomotives with static traction converters equipped with an improved control system.

To achieve this objective, several tasks were solved in the work:

– The analysis of existing control systems for the input converters of the AC electric rolling stock and the structure of the electrical part of the traction electric drive with asynchronous traction motors was conducted.

– A method for reactive power compensation was developed when implementing a leading phase shift of the input current relative to the voltage at the current collector of an electric locomotive with a four-quadrant converter.

– A complex computer model of the system was developed for operation on one feeder zone of two AC electric locomotives with different converter systems.

– An effective method of controlling a four-quadrant converter in the reactive power compensation mode has been chosen.

Elements of scientific novelty included:

– A system of automated control of the traction converter adapted to the changing parameters of the traction network.

– A complex mathematical model of the system «traction network – AC electric locomotive with a four-quadrant (4q-S) converter».

– Technical requirements for new generation AC electric locomotives.

The following research methods were used to solve the problems: numerical and analytical methods for solving differential equations; methods of analysis and calculation of semiconductor converters of electrical energy; methods of mathematical modelling of complex electrical systems; methods of experimental determination of parameters and characteristics of electrical complexes.

The degree of reliability and approbation of the results of the thesis is justified theoretically and is confirmed by the satisfactory agreement of the results obtained in the work with the data of experimental studies obtained during testing of cargo electric locomotives on the experimental ring of the Research Centre VNIIZhT (Shcherbinka), as well as with the results of other researchers, working in this direction.

As a result of the thesis research, based on the analysis of electromagnetic processes in the «traction network – electric locomotive» system, an algorithm for controlling a four-quadrant converter of an electric locomotive operating in traction mode is proposed.

It has been established that when an electric locomotive with a reversible converter operating in

traction mode and an electric locomotive with a four-quadrant converter are located on the same feeder zone, it is possible to maintain the voltage at the required level in the feeder zone by switching the electric locomotive with a four-quadrant converter to the reactive energy generation mode in the contact network. For this purpose, an automated control system for a four-quadrant converter, developed in the thesis and adapted to the changing parameters of the traction network, is proposed.

When analysing domestic and foreign sources of information on the interaction of AC electric rolling stock and traction network, tasks were formulated and concepts for improving the energy efficiency of the electrical system «traction network – electric locomotive» were proposed.

Prospects for further development of the topic may include research on the following issues:

- The possibility of improving the proposed control algorithms for a four-quadrant converter based on signals from contact network voltage sensors installed on operated AC electric locomotives.
- Sensitivity of the control system of the four-quadrant converter to surges of mains current and voltage in the contact network during emergency operation of the traction power supply system.
- The possibility of improving the system in terms of automatic control of four-quadrant converters of several electric locomotives during their parallel operation on the same feeder zone.

05.09.03 – Electrotechnical complexes and systems

The work was performed and defended at Russian University of Transport.

Kaplin, V. N. Current maintenance of the track in the area of rail joints on especially heavy-duty lines using elastic sleeper pads. Abstract of Ph.D. (Eng) thesis [*Tekushchee soderzhanie puti v zone relsovykh stykov na osobo gruzonapryazhennykh liniyakh s primeneniem uprugikh podshpalnykh prokladok. Avtoref. dis… kand. tekh. nauk*]. Moscow, RUT (MIIT) publ., 2022, 24 p.

The expediency of straightening the track in the zone of rail joints by laying elastic sleeper pads on the compacted bed of reinforced concrete sleepers is theoretically and experimentally substantiated. The effectiveness of this technical solution has been confirmed by operational observations during the period of processing of more than eight hundred million tons through the pilot area.

The use of elastic sleeper pads at the joints of equalizing spans of a continuous welded track makes it possible to increase the speed of train processing in case of an excess increase in the gap in winter during the day and, in general, increase the throughput on especially loaded lines.

The objective of the thesis was to determine the effectiveness of the use of various types of sleeper pads placed under the sole of sleepers when straightening settlements in the butt zone within the framework of the current content, based on the analysis of the results of measuring the accumulated deformations of the track, considering the characteristics of labour costs and indicators of track stability.

Research objectives included:

– Theoretical and experimental studies to solve the problems of operation of track joints on reinforced concrete sleepers.

– Technical solutions to improve track stability in the joint area.

The object of the study was the railway track in the zone of rail joints.

The subject of the study was the use of sleeper pads in the process of servicing the railway track in the joint zone to increase its stability.

As a result of the research, solutions were proposed to reduce deformations in the butt zone of the track on reinforced concrete sleepers by laying elastic pads under the sole of sleepers when straightening settlements up to 14 mm with current maintenance of the track.

The possibility of using elastic sleeper pads in the joints on reinforced concrete sleepers to increase the speed of train passage through the gap in the joint up to 32 mm from 25 km/h to 40 km/h is substantiated.

A schedule has been developed for distribution of work when straightening subsidence at the joints on reinforced concrete sleepers with laying of elastic gaskets.

The possibility of using elastic sleeper pads for construction of sections transitional in terms of stiffness from a track without ballast to a standard design has been confirmed.

Possibilities have been proven: the use of elastic sleeper pads for straightening subsidence at joints on reinforced concrete sleepers on especially heavy-duty lines; processing of more than 800 million tons without additional alignment after laying elastic sleeper pads to eliminate subsidence up to 14 mm deep; stability of geometrical and stiffness characteristics of elastic under-sleeper pads after processing of a tonnage of 800 million tons or more.

The choice of stiffness characteristics of elastic sleeper pads is substantiated in terms of accumulation of residual deformations – 40,29 kN/mm.

Theoretical and experimental studies have shown that when using elastic gaskets in the butt zone, vertical forces arising from the interaction of the track and rolling stock are reduced by 1,3 times compared to the typical track design, and accelerations on receiving sleepers of the joint are reduced by 2,9

times by average values and 2,65 times by maximum values.

The use of elastic sleeper pads makes it possible to increase the speed of train processing along the joint with a gap of up to 32 mm from 25 km/h to 40 km/h.

The prospect of research presented in the thesis is to assess the possibility of further increasing the speeds of train processing, depending on design of the joint, and to determine the rational areas of application of the developed joint design in different operating conditions.

2.9.2. Railway track, survey, and design of railways.

The work was performed and defended at Russian University of Transport.

Shapetko, K. V. Influence of irregularities of the longitudinal profile on track deformability, traffic safety and energy consumption for train traction. Abstract of Ph.D. (Eng) thesis [*Vliyanie nerovnostei prodolnogo profilya na deformativnost puti, bezopasnost dvizheniya i raskhod energii na tyagu poezdov. Avtoref. dis… kand. tekh. nauk*]. Moscow, RUT (MIIT) publ., 2022, 24 p.

In modern conditions of operation of railways under the influence of trains of increased mass and length, including cars with increased axial loads, deformations of the track in the longitudinal profile occur not only in the elements of the track superstructure, but also due to uneven settlement of the roadbed, which contributes to the appearance of long irregularities.

Studies of domestic and foreign experts have made it possible to determine the effect of increasing axial loads on the accumulation of track disorders. However, the process of determining deformability of a railway track by the parameters of irregularities in the profile has not been studied in full due to the lack of tools and standards for determining them in real time.

The relevance of the work is a consequence of the need to develop studies to determine the parameters of the longitudinal profile irregularities and subsequent monitoring of the state of the track by changing the characteristics of these irregularities in areas of heavy traffic, including in the areas of circulation of cars with increased axial loads, as well as the impact of these irregularities on traffic safety and consumption. energy for train traction.

The experience studied by the author made it possible to implement a method for obtaining the parameters of long irregularities for monitoring the railway track according to the measuring systems of track meters to determine the parameters of long irregularities and track deformability, as well as to carry out calculations and experiments to assess the effect of irregularities on traffic safety and electricity consumption for train traction.

The objective of the study was to determine and monitor the parameters of long longitudinal profile irregularities, the presence of which on the track has a significant impact on track deformability, traffic safety and electricity consumption for train traction.

Research objectives included:

– Development of proposals for assessing track deformability based on data on changes in the parameters of long irregularities in the longitudinal profile.

– Assessment of the impact of long irregularities on traffic safety.

– Assessment of the impact of long longitudinal profile irregularities on the energy consumption for train traction.

The object of the study was associated with the sections of the railway track with long irregularities of the longitudinal profile, the change in the parameters of which may indicate possible (probable) places of deformations of the roadbed.

The subject of the study was the natural irregularities of the longitudinal profile of the track, obtained by geodetic methods from reference systems external to the track, or similar indicators obtained by numerical processing of data from the measuring systems of the track gauge. This made it possible to determine changes in the parameters of irregularities in time, considering the processed tonnage, their influence on track disorders caused by deformability of the base, traffic safety and energy consumption. By «natural» we mean irregularities that describe the real position of the track in the profile in an independent coordinate system and change with an increase in the tonnage processed.

The results obtained during implementation, testing and verification for research purposes of the method for determining the parameters of irregularities of the longitudinal profile, made it possible to prove that the values of long irregularities can be elements of assessing track deformability.

Indicators for assessing track deformability in the longitudinal profile were proposed and implemented.

The data obtained make it possible to analyse the effect of long irregularities caused by track deformability on traffic safety during rolling stock derailments and additional power consumption for train traction.

A new definition of «long irregularity» is introduced as a deviation of the position of a track of a uniform slope in the longitudinal profile, obtained by geodetic methods from external reference points in relation to the track or by the transformation method presented in the work.

The indicators for assessing track deformability based on the data of changes in the parameters of

long irregularities in the longitudinal profile are proposed, which are included in the updated methodology for assessing the impact of rolling stock on the track according to the conditions for ensuring reliability, approved by order of JSC Russian Railways No. 2706/r dated December 22, 2017.

A methodology and a calculation model for monitoring the state of the track by the parameters of long irregularities of the longitudinal profile are developed, which are included in the method of additional monitoring of the state of the track by the parameters of long irregularities of the longitudinal profile, based on the ratio of the length, amplitude, and areas of irregularities, approved by order of JSC Russian Railways No. 2191/r dated October 03, 2019

The main provisions of the methodology for determining the parameters of long irregularities for their monitoring during operation are outlined.

The systematized results of monitoring long irregularities in different regions of the network are presented.

The dependences of the change in the parameters of long irregularities on the processed tonnage are disclosed.

The influence of long irregularities of the longitudinal profile on safety of train traffic is proved.

A system of practical recommendations has been created in terms of monitoring track state parameters according to data containing changes in the characteristics of long longitudinal profile irregularities.

The economic effect is determined from the elimination of long irregularities of the longitudinal profile, which affect the electricity consumption for train traction, which is 157 thousand rubles per 100 km of track with long irregularities at a load density of one hundred million gross tons per day.

The prospect of further development of the topic is to assess the relationship between the parameters of long irregularities and the dynamics of rolling stock in a wide range of speeds and outlines of the profile of long irregularities with development of recommendations for using the results obtained in preparation of the order of JSC Russian Railways on the permissible speeds of trains along the track in the presence of long irregularities.

2.9.2. Railway track, survey, and design of railways.

The work was performed at the Joint Stock Company «Scientific Research Institute of Railway Transport» (JSC «VNIIZhT»), defended at the Russian University of Transport.

Sokolov, D. A. Improving the methodology for calculating and selecting reactive power compensation devices in the traction power supply system. Abstract of Ph.D. (Eng) thesis [*Sovershenstvovanie metodiki rascheta i vybora ustroistv kompensatsii reaktivnoi moshchnosti v sisteme tyagovogo elektrosnabzheniya. Avtoref. dis… kand. tekh. nauk*]. St. Petersburg, PGUPS publ., 2022, 16 p.

In connection with the growing need for a wider use of energy-saving technologies, as well as with the growth of electricity tariffs, the problem of increasing energy efficiency in railway transport has become more and more acute in recent years. The energy strategy of JSC Russian Railways contains, among other things, the issues of energy saving in the traction power supply system.

One of the ways to improve energy efficiency in traction power supply is capacitive reactive power compensation.

This paper considers compensating devices installed in the AC traction network. These devices are quite widespread on the range of railways in our country.

In traction power supply systems of AC railways, a considerable number of unregulated transverse capacitive compensation devices are installed. At the same time, the existing method for choosing their power is based, first, on the need to increase the voltage level and ensure the required bandwidth.

The work was aimed at improving the existing methodology for selecting compensating devices and involves considering power losses in the traction network directly when choosing the power of compensating devices, based on an analysis of the train schedule, along with maintaining the required voltage level at the rolling stock pantograph.

The object of the study was the transverse capacitive compensation devices installed in the AC traction power supply system.

The subject of the study was the methodology for selecting and calculating devices for transverse capacitive reactive power compensation.

The objective of the study was to improve the methodology for choosing the type and power of transverse capacitive compensation devices.

The study analyses the influence of locations and parameters of compensating devices on the level of power losses in the traction network.

Methods for calculating the parameters of a traction power supply system using probability theory and mathematical statistics are considered.

An improved method for selecting and calculating transverse reactive power compensation devices has been developed, which involves statistical processing of the train traffic schedule and considering power losses in the traction network.

A software package has been created for calculating the AC traction power supply system, considering the resistance of the power system, the contact network in which is presented in the form of a line with distributed parameters.

The proposed program was verified by comparing the results with calculations in KORTES complex, physical modelling, and data from AIISKUE automated information-measuring system, tests on a physical model of a particular section of the railway.

In the developed complex, based on the probabilistic analysis of the train schedule, the parameters of the traction power supply system were calculated when compensating devices of several types and capacities were installed at the sectioning post.

According to the methods approved by JSC Russian Railways for the selection and calculation of compensating devices in traction power supply systems, the calculated power of the compensating device installed at the sectioning post was determined – 13,37 Mvar. In this case, the total average daily reactive power consumed for train traction in the considered inter-substation zone is 6,4 Mvar, and therefore the power of the compensating device must be selected according to the latter value. However, for the system under consideration, the maximum possible power of the compensating device according to the condition of limiting the voltage level to 29 kV is only 2,3 Mvar, the value of which was chosen for modelling.

Even though, according to the condition of the maximum allowable voltage, the selected power of the unregulated compensating device turned out to be 5,9 times less than that required to increase the minimum three-minute voltage, the simulation process showed an increase in this value from 18,53 to 20,6 kV, which is only 2 % below acceptable. At the same time, power losses in the traction network remained practically unchanged.

The case of installing a two-stage compensating device is also considered, the power of the first stage of which is half that of the statistically most probable power consumed by the load. The power of the additional stage used in case of an unacceptable voltage drop is selected according to the condition of increasing the minimum instantaneous voltage level to 21 kV. In this case, power losses in the traction network are reduced by 26 %.

In case of using a three-stage device, the power of the stages of which is chosen to be half the average reactive power consumed by one, two and three trains, respectively, the voltage level in the contact network does not fall below 22,6 kV, and the power losses in the traction network are reduced by 28 %.

Operating experience of compensating devices with smooth regulation shows that their use, provided that the voltage is maintained at a level of 25 kV, can reduce power losses by half.

The assessment of the level of electricity losses in the traction network when using several types of compensating devices in relation to their cost showed that the most advantageous in terms of reducing losses is a two-stage compensating device. At the same time, all of them provide the required voltage level at the current collector of the electric locomotive in the considered section. The relative cost of compensating devices is compared with the most expensive of them – with smooth regulation.

Subject to the requirements for the minimum allowable voltage level in the contact network, depending on the traffic schedule and the consumed reactive power, it is advisable to choose single- and multi-stage compensating devices to minimize power losses. Given the current level of development of automation devices and switching equipment, the installation of non-adjustable non-switchable compensating devices is not recommended. The use of compensating devices with smooth control should be due to the need for a significant increase in throughput in the area under consideration.

The thesis shows that power losses in the traction network do not change when compensating devices are installed, the power of which is selected according to the reactive power consumed by trains. The greatest effect from the installation of compensating devices in terms of reducing losses in the traction network is achieved when the power of the compensating device is 50 % of the reactive power consumed by electric rolling stock.

An improved method for selecting and calculating transverse reactive power compensation devices has been formulated, which implies the choice of the type and power of compensating devices based on statistical processing of the train schedule, considering power losses.

A software package has been developed for calculating the parameters of an AC traction power supply system in MATLAB-Simulink. Its reliability is confirmed by a low (no more than 12 %) error when comparing the results of calculations with the data of AISKUE system, calculations in KORTES complex and tests on a physical model of a particular section of the railway, as well as three certificates of registration of a computer program.

The effectiveness of the proposed method for calculating and choosing compensating devices during its testing on a model of a particular section of the railway is proved. All the considered devices provide the required voltage level in the contact network, however, the choice of their type and power based on the statistical processing of the train traffic schedule makes it possible to reduce power losses in the traction network by 26 %.

05.09.03 – Electrotechnical complexes and systems.

The work was performed and defended at Emperor Alexander I St. Petersburg State Transport University.