

Министерство науки и высшего образования Российской Федерации  
НОВОСИБИРСКИЙ ГОСУДАРСТВЕННЫЙ ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

---

# PROGRESS THROUGH INNOVATIONS

PROCEEDINGS 2024  
XII<sup>th</sup> INTERNATIONAL  
ACADEMIC AND RESEARCH CONFERENCE  
OF GRADUATE AND POSTGRADUATE STUDENTS

March 28, 2024  
Novosibirsk, Russia

ТРУДЫ XII МЕЖДУНАРОДНОЙ НАУЧНО-ПРАКТИЧЕСКОЙ  
КОНФЕРЕНЦИИ АСПИРАНТОВ И МАГИСТРАНТОВ

Новосибирск, 28 марта, 2024 г.

НОВОСИБИРСК  
2024

ББК 65.291.551я431 + 72я431  
Р 93

Ответственный редактор М. А. Салтымакова

Organized by Department of Foreign  
Languages for Technical Faculties

Organized by Novosibirsk State Technical University

Р93 **Progress through Innovations.** Proceedings 2024 XII<sup>th</sup> International Academic and Research Conference of Graduate and Postgraduate Students: труды XII международной научно-практической конференции аспирантов и магистрантов / отв. ред. М. А. Салтымакова. – Новосибирск: Изд-во НГТУ, 2024. – 169 с.

ISBN 978-5-7782-5218-9

Сборник трудов аспирантов и магистрантов вузов России представляет работы, обсуждавшиеся на научно-практической конференции, посвященной различным проблемам в области техники, информационных технологий и экономики.

**ББК 65.291.551я431 + 72я431**

**ISBN 978-5-7782-5218-9**

© Коллектив авторов, 2024  
© Новосибирский государственный  
технический университет, 2024

## Contents

### AUTOMATION AND COMPUTER ENGINEERING

<b>Gaponko Anton, Yakovina Irina N.</b> <i>On the development of fibroscan application and database.....</i>	<b>7</b>
<b>Karavaev Valentin</b> <i>The development of a method for assessing human hearing and a device for its implementation.....</i>	<b>9</b>
<b>Kochev Danil, Yakovina Irina N., Osipenko Ivan V.</b> <i>Development of a diagnostic calculator to assess the form and stage of inflammatory bowel disease.....</i>	<b>12</b>
<b>Kudryavtsev Stepan, Yakovina Irina N.</b> <i>Development of a Vacancy Monitoring Service.....</i>	<b>15</b>
<b>Moiseenko Anastasia, Bychkov A.</b> <i>Selecting data to create a dataset for modeling the decision-making process for issuing a consumer loan .....</i>	<b>18</b>
<b>Shakhova Ann</b> <i>Utilizing digital footprint technology for planning urban tourist routes: a case study in the Novosibirsk region.....</i>	<b>20</b>
<b>Shcherbakova Irina</b> <i>Advantages and disadvantages of simulation modeling.....</i>	<b>23</b>
<b>Shevlyakov Roman</b> <i>Achieved progress on development of uniqueness controlling software.....</i>	<b>26</b>
<b>Skibin Pavel</b> <i>Video compression using quantization.....</i>	<b>28</b>
<b>Vasilchenko Tatyana</b> <i>Development of a dataset of syntactic structures for machine translation of Russian sign language .....</i>	<b>29</b>
<b>Voitsekhovich Igor</b> <i>Software and Systems Analysis of Research on Device and Service Interaction in the Internet of Things Systems.....</i>	<b>31</b>
<b>Denisov Maxim, Yakovina Irina N.</b> <i>Features of the development of maintenance instructions for an industrial plant using mixed reality technology .....</i>	<b>32</b>
<b>Tyvoniak Alexandr</b> <i>Abstract Title – The System of Analysis and Control of Educational Materials for Plagiarism .....</i>	<b>35</b>

### POWER ENGINEERING

<b>Averyanov Sergey</b> <i>Analysis of transient modeling approaches for data forecasting.....</i>	<b>37</b>
<b>Arkhipov Alexander</b> <i>Development of Modeling Methods for Hydro Turbine Regulators.....</i>	<b>40</b>
<b>Goduntsov Roman</b> <i>Measurement of Very Fast Front Overvoltage in Condition of Operated Substations.....</i>	<b>43</b>
<b>Evdokimov Artem</b> <i>Improvement of Algorithms of Operation of Equipment Overload Limitation Automatics.....</i>	<b>46</b>
<b>Zubov Viktor</b> <i>Low-Resistance Neutral Grounding In 6-35 kV Networks .....</i>	<b>48</b>

<b>Ilina Viktoria</b> <i>Applicability of Normative-Legal Basis for Error Testing of Current Transformers of Classes 10P and 10 PR.....</i>	<b>50</b>
<b>Kostoglodov Artem</b> <i>Peculiarities of Classification of Auto Reclosing Lines .....</i>	<b>52</b>
<b>Kotikov Evgeny</b> <i>Improving the methodology for planning power system operating modes when introducing renewable energy sources.....</i>	<b>54</b>
<b>Kurtukov Alexey</b> <i>Development of an algorithm for automatic calculation of distance line protection.....</i>	<b>57</b>
<b>Less Vitaly</b> <i>Review of the existing methods of power quality improving in electric power systems with traction load.....</i>	<b>59</b>
<b>Motyk Ivan</b> <i>Comparative analysis of the Allam cycle and combined cycle power plants.....</i>	<b>62</b>
<b>Odinabekov Mukhammadzhon</b> <i>Express Limitation of Frequency Reduction and Increase in Local Intelligent Power Systems.....</i>	<b>64</b>
<b>Pribilsky Ilya</b> <i>Control algorithm of the network with small distributed generation based on Large Language Model.....</i>	<b>66</b>
<b>Seimov Kirill</b> <i>Development of a program for Selection of Emergency Mode Parameters for Testing of OOSP Devices.....</i>	<b>69</b>
<b>Sergeev Yuri</b> <i>Construction of a Highly Automated Digital Substation.....</i>	<b>72</b>
<b>Sidorov Andrey</b> <i>Development of the Technique for Calculating Distance Line Protection.....</i>	<b>73</b>
<b>Sorokopudov Dmitry</b> <i>Modelling of a Hydroelectric Power Plant.....</i>	<b>76</b>
<b>Stepanov Alexander</b> <i>Overview of Novosibirsk Thermal Power Stations.....</i>	<b>78</b>
<b>Shvets Nikolay</b> <i>UV-inspection of External HV Insulation.....</i>	<b>81</b>
<b>Evseenko Pavel</b> <i>Creation of a Coal-to-gas Switch Estimation Methodology in the Electric Power Generation Sector.....</i>	<b>83</b>
<b>Kolesnikov Daniil</b> <i>Analysis of the development of accidents in a power system with a large share of RES.....</i>	<b>86</b>

## **MECATRONICS AND AUTOMATION**

<b>Andreev Maxim</b> <i>The research of electromagnetic and hydrodynamic processes during levitational melting of aluminum products.....</i>	<b>89</b>
<b>Trofimenko Alexandr, Kotin Denis A.</b> <i>Development of a shuttle accelerator based on a linear electric motor.....</i>	<b>92</b>
<b>Pridatchenko Timofey, Kotin Denis A.</b> <i>Magnetic belt accelerator of the weft thread plotter of the loom.....</i>	<b>95</b>
<b>Menschikov Andrei</b> <i>Energy efficiency of lithium battery balancers.....</i>	<b>98</b>
<b>Fonyakin Anton, Chestyunina Tatyana V.</b> <i>Improving Efficiency of Synchronous Generator with Permanent Magnets.....</i>	<b>101</b>

## **MECHANICAL ENGINEERING**

<b>Lanshakov Ilya, Eyrych Richard</b> <i>All-terrain vehicle performance calculations...</i>	<b>104</b>
<b>Burkhinova Nomina</b> <i>Influence of calcium hexaaluminate on physical and mechanical properties of alumina-zirconia based ceramics.....</i>	<b>106</b>
<b>Permikin Maxim, Ivanova Maria</b> <i>Selection of Rational Technology for Composite Aerospace Products Manufacturing.....</i>	<b>109</b>

## **PHYSICAL ENGINEERING**

<b>Krysenko Denis</b> <i>Laser cooling of ytterbium-171 ion in the field of three light waves.....</i>	<b>112</b>
<b>Golubovsky Maksim</b> <i>Modeling absorption infrared triplet of oxygen atom in the atmosphere of the exoplanet KELT-9b.....</i>	<b>113</b>

## **RADIO ENGINEERING AND ELECTRONICS**

<b>Alushkin Egor</b> <i>Research of DMR signal demodulation using practical implementation technique.....</i>	<b>116</b>
---	------------

## **THERMAL AND ELECTRIC ENERGY PRODUCTION**

<b>Vinogradov Sergey, Pochtar Anton</b> <i>Ignition of blended fuel consisting of high-ash coal and sawdust.....</i>	<b>117</b>
<b>Muravev Igor</b> <i>Overview of combustion technology, moderate or intensive low-oxygen dilution.....</i>	<b>120</b>
<b>Dorofeev Andrey</b> <i>Scheme for utilization of flue gases from petroleum coke calcination plant.....</i>	<b>122</b>
<b>Pochtar Anton</b> <i>Oil-free ignition of pulverized coal-fired boiler units.....</i>	<b>125</b>
<b>Potkin Nikita</b> <i>Review of technologies for reducing nitrogen oxide emissions from thermal power plants. Low-emission burner systems.....</i>	<b>128</b>
<b>Poleva Anastasia</b> <i>Technologies for ensuring environmental safety of coal POWER engineering.....</i>	<b>132</b>
<b>Shpilevskaya Dariana</b> <i>Analysis of environmental efficiency change during replacement of flue gas desulfurization unit.....</i>	<b>134</b>

## **BUSINESS AND ECONOMICS**

<b>Nikitin Maksim</b> <i>Information Support for Analysis of Enterprise Activities Abstract.....</i>	<b>136</b>
<b>Potekhin Nikita</b> <i>Impact of the use of digital technologies in construction time management .....</i>	<b>139</b>

## **GERMAN SESSION**

<b>Dik Dmitry</b> <i>Herstellung, Mikrostruktur und mechanische Eigenschaften von Borkarbid-Chromdiborid Keramik .....</i>	<b>142</b>
<b>Potekhina Natalia</b> <i>Anpassung von Webschnittstellen auf der Grundlage einer Analyse des Nutzerverhaltens.....</i>	<b>145</b>
<b>Kharin Sergey</b> <i>Entwicklung eines Geräts zur Überwachung der orthopädischen Körperhaltung.....</i>	<b>148</b>
<b>Kabanova Irina</b> <i>Entwicklung einer auf Computer Vision basierenden mobilen Software zur Bewertung der Rindfleischqualität.....</i>	<b>151</b>
<b>Mirganov Pavel</b> <i>Erforschung verschiedener Arten von elektrischen Energiespeichern .....</i>	<b>154</b>
<b>Neudakhin Artemiy</b> <i>Etappen der Entwicklung einer spezialisierten Werkzeugmaschine für die Metallbearbeitung.....</i>	<b>157</b>
<b>Schweigert Egor</b> <i>H-Brücke-Steuersystem im Notbetrieb.....</i>	<b>160</b>
<b>Eyrich Richard, Lanshakov Ilya</b> <i>Optimierung der Getriebeparameter für den Geländewagen «Predator 3930».....</i>	<b>165</b>

## AUTOMATION AND COMPUTER ENGINEERING

### **On the development of fibroscan application and database**

**Anton Gaponko**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[gaponko.2019@corp.nstu.ru](mailto:gaponko.2019@corp.nstu.ru)

**Irina N. Yakovina**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[yakovina@corp.nstu.ru](mailto:yakovina@corp.nstu.ru)

***Abstract:** In the era of healthcare digitalization, effective data management is becoming a key aspect of providing quality medical care. However, the existing limitations of official software for working with medical devices such as “Fibroscan”, create the need to develop specialized applications. This paper presents the results of the development and implementation of a medical information system “Fibroscan” designed to collect, store and analyze data concerning patients and their visits.*

***Keywords:** desktop, database, medical system, MVC, FXML.*

Systems for the collection and management of medical data enable rapid analysis and effective diagnosis, monitoring and treatment of patients, as well as contribute to solving research problems and exchanging medical information [1]. For many apparatus and devices used in practice there is a need to develop and implement information systems and databases.

#### **The purpose of the project**

The purpose of this project was to develop and implement a medical information system “Fibroscan”, designed for collection, systematization and processing of data obtained from the medical device “Fibroscan”. The customer was the Laboratory of Gastroenterology of the Research Institute of Internal and Preventive Medicine – a branch of the Institute of Cytology and Genetics, Siberian branch of Russian Academy of Sciences. The developed system allows one to provide convenient collection and storage of information about patients and their visits, as well as to solve the tasks of primary analysis of data on the dynamics of patient parameters by doctors.

#### **Main objectives of the project**

1. Analyzing the market and existing developments in the field.
2. Developing the terms of reference based on the needs of the customer (Laboratory of Gastroenterology of the Research Institute of Therapy and Preventive Medicine).

3. Designing a database to store information about patients and their visits.
4. Developing the application using Model-View-Controller architecture and Data Mapper pattern.
5. Developing modules for handling patient and visit data, as well as a visit analysis module and a file upload module.
6. Conducting an iterative development of the application interface to incorporate feedback and statistical data.
7. Conducting real-world testing and collecting feedback to improve the quality of the application.

### **Database structure and application architecture**

The application database was designed to store information about patients and their visits. The first module of the database contains data about the patient's medical history, including information about the patient's diseases and lifestyle. Tables in the second module describe each of the patient's visits, capturing patient dynamics such as degree of fibrosis and body mass index. This allows maintaining a detailed history of the patient's medical conditions and tracking the patient's condition over time.

The “Fibroscan” application was developed using Model-View-Controller (MVC) architecture [2]. The layout of the interface is done through FXML files. The Controller layer manages interface and data interaction, and the Model layer, built using the Data Mapper pattern, provides efficient data exchange with the database.

The application includes four main modules:

1. A module for working with patient and visit data that allows one to create, update, delete and modify information.
2. A visit analysis module that provides visual statistics using graphs and numerical indicators.
3. A file upload module that makes it easy to upload large amounts of information automatically.
4. A module for working with patient anamnesis and medical history.

Testing was an important part of the development, including writing unit tests and real-world testing. The application was implemented in test mode to collect feedback, which allowed identifying and fixing existing bugs and improving functionality.



## Conclusion

The “Fibrosan” medical information system developed was an important step in improving healthcare efficiency and providing convenient and reliable management of patient and visit data. This project demonstrates how modern information technology can support and improve the quality of medical practice, research and medical information exchange.

## References

1. Data Science in Medicine: Who, How and Why Processes Data [Electronic resource]. URL: <https://hightech.fm/2021/07/16/data-science-medicine>.
2. Design Patterns – MVC Pattern [Electronic resource]. URL: [https://www.tutorialspoint.com/design\\_pattern/mvc\\_pattern.html](https://www.tutorialspoint.com/design_pattern/mvc_pattern.html)

**Research adviser:** Assoc. Prof. Irina N. Yakovina, Ph.D. in Engineering

**Language adviser:** Assoc. Prof. Gleb V. Toropchin, Ph.D. (Cand. Sc.) in History

## The development of a method for assessing human hearing and a device for its implementation

**Valentin Karavaev**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[karavaev.2019@stud.nstu.ru](mailto:karavaev.2019@stud.nstu.ru)

***Abstract:** The article provides statistics on the hearing impairment prevalence. The application of audiometers as a practical, but not widely used hearing diagnostic tool is considered. Possible improvements to clinical audiometers and hearing examination methods implemented with their help are proposed. The functionality of a working device prototype is described and the upcoming steps to improve it are shown.*

***Keywords:** pure-tone audiometry, hearing loss, prototype*

Recent statistics from the World Health Organization (WHO) showed that today, about 470 million people have hearing loss. In terms of prevalence, hearing loss ranks third in the world, behind heart disease and arthritis. By 2050, WHO predicts partial or complete hearing loss in a quarter of the world’s population [1].

All this shows the relevance of the problem and the lack of research into it. The large number of people listed in the statistics are only established cases. Most often hearing loss develops unnoticed, and timely detection of it

would allow treatment to begin at an early stage of the disease before it is too late.

A great deal of previous research on this issue has focused on the development and implementation of special devices called audiometers. Their main task is to conduct pure-tone audiometry, as a result of which four audiograms are constructed and analyzed. An audiogram refers to the dependence of sound frequency on the intensity at which the current frequency was heard by the patient. The otolaryngologist needs to test patient's ears separately for both air and bone conduction.

Air conduction organizes the natural way of perceiving sound through the eardrum and the ossicular system. However, few people know that a person can also sense sound mechanically through vibrations. It is possible due to the bones of the skull, which implement bone conduction and provide sound perception directly to the inner ear, bypassing the eardrum and the ossicular system. Based on the audiograms obtained, two parameters are calculated – the air-bone interval and the hearing impairment level, which are used to determine the type and degree of hearing loss [2].

Articles on this topic show that pure-tone audiometry is a practical tool that allows you to test each ear and, most importantly, detect hearing loss at an early stage. In addition, audiometry is cheaper and easier to perform than other hearing testing methods such as tympanometry, acoustic reflexometry and impedance testing.

Meanwhile, today it is difficult to find even audiometers in medical institutions. Otolaryngologists practice whisper audiometry, during which the doctor whispers words and the patient repeats them. Of course, this method is even simpler than those listed above and reduces the examination time of one patient, but it gives an approximate testing of hearing, whose result is the distance from which the whisper was heard correctly. Hearing testing is also recommended in workplaces with high noise levels and should be given to staff to prevent ear congestion after each shift. However, a practice shows, that audiometry does not carry out even in the context of whisper procedure.

So, the purpose of this study is to develop existing clinical audiometers by providing them with new modes to evaluate additional human hearing abilities. The proposed device should be more accessible and cheaper than other non-invasive diagnostic tools. Its great research potential is due to the

combination of several different hearing testing methods to create a complete picture of the patient's hearing.

Fig. 1 shows a working prototype of the device. Its development was based on the following stages: selection of components, writing program code, programming the microcontroller, design of the case and printed circuit board. In the prototype, in addition to the classic pure-tone audiometry mode, hearing thresholds, relative pitch and absolute pitch are measured. Normal relative pitch is understood here as a person's ability to correctly identify a sound that differs from others in a specific parameter – frequency, intensity or duration of sound. The presence of absolute pitch indicates an ability to determine the note from a certain octave without reference to other sounds. With these modes, the device can be considered a simulator, because the new measured hearing abilities can be improved with proper practice.

The operating modes of the prototype coordinate intelligently with each other and together allow for a better and more complete examination of the hearing organs. The hypothesis is that different pathologies affect each individual hearing ability differently. If two pathologies have the same effect, for example, on hearing thresholds, then the remaining modes will help clarify the diagnosis.



*Fig. 1 – Developed prototype of a hearing assessment device*

Further research of the finished prototype will allow us to improve the method being developed and compile a final list of the most important hearing parameters for measuring. Conducting heuristic research and usability testing will help identify vulnerabilities in the software and interface design of the current device version.

Thus, instruments for assessing hearing abilities are an integral part of the diagnosis and detection of hearing problems, both in cases of obvious impairments and in the early stages of pathologies. The creation of a device that provides a comprehensive assessment of several hearing abilities is an important step towards improving current audiometers and adding new useful functionality to them.

### References

1. Narushenie slukha v tsifrah (statistika) [Hearing impairment in numbers (statistics)] [Electronic resource]. – 2023. – URL: <https://sluh.online/statistika>.
2. Kovalenko S.L. Kak rasshifrovat' audiogrammu – podrobnoe rukovodstvo ot vracha [How to decipher an audiogram - a detailed guide from a doctor] [Electronic resource]. – URL: <http://eu-max.ru/blog/audiogram/>.

**Research adviser:** Assoc. Prof. Aleksandr V. Pavlov, Ph.D. in Biology

**Language adviser:** Assoc. Prof. Dina D. Sin, PhD in geological and mineralogical sciences

### Development of a diagnostic calculator to assess the form and stage of inflammatory bowel disease

**Danil Kochev**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[kochev.2019@stud.nstu.ru](mailto:kochev.2019@stud.nstu.ru)

**Irina N. Yakovina**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[yakovina@corp.nstu.ru](mailto:yakovina@corp.nstu.ru)

**Ivan V. Osipenko**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[osipenko.2012@corp.nstu.ru](mailto:osipenko.2012@corp.nstu.ru)

**Abstract:** *The paper presents the result of developing a diagnostic calculator for assessing the form and stage of inflammatory bowel diseases. Analogs were analyzed and requirements for the application were formulated. The developed web application consists of three modules, allowing the user to work with input and file-loaded data.*

**Keywords:** *diagnostic calculator, Streamlit, web application.*

Modern technologies allow reducing the complexity of gathering expert data and forming models of primary diagnosis using methods and means of machine learning. Trained machine learning models with high accuracy can

perform the task of classifying sets of indicators, which is the process of conducting primary disease diagnosis.

Diagnostic calculators based on various clinical and laboratory indicators enable determining the severity of the disease, assessing the likelihood of complications, and refining the long-term prognosis.

Examples of successful medical risk calculators, such as SCORE and FRAX, demonstrate the significance of such tools in modern medicine. For instance, FRAX assesses the risk of fractures associated with osteoporosis [1]. The developing calculator is intended for assessing inflammatory bowel diseases and provides physicians with a tool for more accurate diagnosis and forecasting.

The task of developing a diagnostic calculator to assess the form and stage of inflammatory bowel diseases was addressed within this project. The customer was the Research Institute of Internal and Preventive Medicine of the Institute of Cytology and Genetics, Siberian Branch of Russian Academy of Sciences.

Among the formulated requirements, the following can be highlighted: the programming language should have high performance and be capable of processing large volumes of data. The library should have an extensive set of tools for working with machine learning and neural networks. The library should support machine learning models created using Orange 3, as provided by the customer.

Python and the Streamlit library meet all the listed requirements, which is why they were chosen for developing this web application. Streamlit is an open-source Python library designed for creating interactive web applications.

It is important to note that Streamlit is not a full backend; its main purpose is to create an interactive interface and visualize data. However, it can easily interact with other Python tools and libraries used for data processing, machine learning, and other tasks.

Using the Streamlit library is justified for this application because it does not require complex backend logic and focuses on interacting with machine learning models. The advantages of Streamlit enable the creation of a simple and understandable application that supports working with machine learning technologies.

The library provides a wide range of input and output elements, as well as functions for working with text information, displaying data groups, showing graphs and diagrams, and interactive data input elements.

An important feature of the application is that all data entered on the main page or loaded from a file can be used on other pages.

In the initial phase of the research, similar solutions were analyzed, such as risk calculators, including the Mayo Score, widely used in the medical community.

The main components of the Streamlit library, as well as its core concepts and operating principles, were studied [2]. Additionally, more advanced capabilities provided by this library were explored.

Based on the analysis of similar developments presented by the customer, including databases and diagnostic models, a web application (Figure 1) was developed. It comprises three modules: the main page, a module for working with machine learning models, and a module for working with files.

The developed web application allows users to input patient data, obtain results from 5 different machine learning models, and view additional information about the performance of these models. Additionally, to simplify the diagnosis of a large number of patients, a module for working with Excel files was developed. This module enables users to upload, view, and process tables containing patient data, and then download the results as a file.

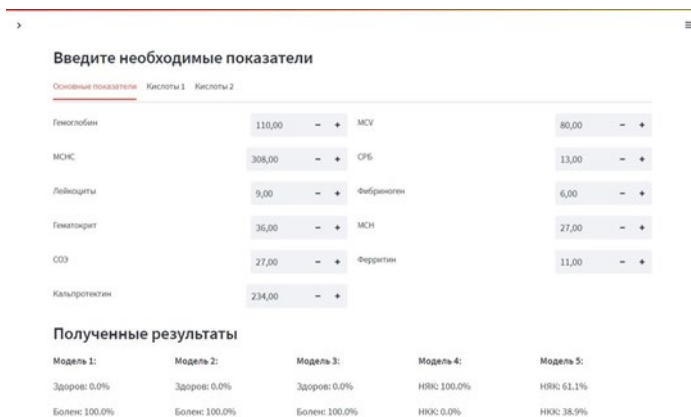


Figure 1 – Example of the web application in operation.

The long-term development prospects of the project include further refinement of functionality for processing the results of model operations and potential integration with other systems and patient databases.

## References

1. Kanis J.A., Oden A., Johansson H., Borgstrom F., Strom O., McCloskey I.V. FRAX – A new tool for the assessment of fracture risk: application in clinical practice and thresholds for intervention. *Osteoporosis and Bone Diseases*. 2012;15(2):38-44.
2. Streamlit – API Reference URL: <https://streamlit-docs.netlify.app/library/api-reference>.

**Research adviser:** Assoc. Prof. Irina N. Yakovina, Ph.D. in Engineering

**Language adviser:** Assoc. Prof. Gleb V. Toropchin, Ph.D. (Cand. Sc.) in History

## Development of a Vacancy Monitoring Service

Stepan Kudryavtsev, Novosibirsk State Technical University, Novosibirsk, Russia, [kudryavcev.2023@stud.nstu.ru](mailto:kudryavcev.2023@stud.nstu.ru)

Irina N. Yakovina, Novosibirsk State Technical University, Novosibirsk, Russia, [yakovina@corp.nstu.ru](mailto:yakovina@corp.nstu.ru)

**Abstract:** *This paper presents the result of developing a job tracking service. This application is a convenient tool for job search using certain filters. This service, developed using the Python programming language and PyCharm environment, allows you to collect information about vacancies from popular websites hh.ru, superjob.ru and trudvsem.ru using the corresponding APIs (Application Programming Interface).*

**Keywords:** *data collection, job search, telegram-bot, API, python.*

A vacancy monitoring service in a job search situation can be used as a tool by many people for whom the issue of employment is a relevant one. The large amount of information about vacancies presented on various websites complicates the search process. In this regard, the development of software that helps job seekers to quickly find suitable vacancies is relevant and socially demanded.

To collect data on vacancies, the developed service uses integration with the websites hh.ru, superjob.ru and trudvsem.ru using their API (see Fig. 1). The service receives job vacancies in JSON format using a GET request [1]. This enables access to up-to-date and accurate information about vacancies, including such parameters as job title, city and salary. This approach simplifies and speeds up the job search for users and provides more accurate results taking into account their preferences.

During the development of a service or a website with the help of APIs, it is possible to implement the functions of a third-party application into the product being developed, customizing them “for yourself” [2]. Such services are Yandex.Maps or payment processing [3].

Since the job tracking service consists of a server side and a client side, the Python programming language was chosen to code the server side of the application, and it was decided to use Telegram Bot as the client side. The Python programming language was chosen to create the server side of the application because of its rich ecosystem of libraries and frameworks, including Flask and Django, simplicity of code, wide community of developers and easy integration with other services and APIs. These advantages make Python a powerful and convenient choice for building a server-side application. However, the interpreted nature of Python can have a negative impact on performance, and GIL can limit multithreading.





*Figure 1 – Algorithm for obtaining information on vacancies*

The client part is a Telegram bot. A Telegram bot is a program that runs in Telegram messenger and uses Telegram API to interact with users. Telegram was chosen for the client part of the job tracking application due to its popularity, simple interface, instant notifications and support for chatbots.

To create a Telegram bot, a client needs to register it through BotFather, install libraries for Python, and create logic for command and message handlers. These handlers allow the bot to respond to commands, text requests, and interact with users via interactive buttons. Telegram also provides a high level of data security and privacy, which is important when dealing with users' personal information.

The development environment used was PyCharm, an integrated development environment for Python that provides full Python support, the ability to create virtual environments, debugging tools, profiling tools, and a user-friendly code editor. It also integrates with version control systems, supports various frameworks and provides a rich set of development tools. There are two versions: a free Community Edition and a paid Professional Edition, with advanced functionality, including support for additional languages, frameworks and build tools.

The result of the software solution development is a convenient and effective tool for monitoring vacancies. This solution helps job seekers to find suitable options and significantly saves time and effort previously spent on manual search.

Thus, the developed software solution based on the use of Python, PyCharm and APIs of the websites hh.ru, superjob.ru and trudvsem.ru is a useful tool for monitoring and searching for vacancies.

### References:

1. 1. What is the difference between parsing and API? [Electronic resource]. URL: <https://scanhub.ru/v-chem-raznica-mezhdu-parsingom-i-api>.
2. A simple guide to the OSI network model for beginners [Electronic resource]. URL: <https://selectel.ru/blog/osi-for-beginners>.
3. V.L. Lukinov, K.V. Samila Creating an aggregator website // Modern problems of telecommunications: Materials of the Russian Scientific and Technical Conference, Novosibirsk, April 20-21, 2022. - Novosibirsk: Siberian State University of Telecommunications and Informatics, 2022. - P. 72-78.
4. Python. [Electronic resource] // URL: <https://www.python.org>.
5. SuperJob API: documentation and libraries [Electronic resource]. URL: <https://api.superjob.ru>.
6. Work in Russia API: documentation and libraries [Electronic resource]. URL: <https://trudvsem.ru/opendata/api>.
7. HeadHunter API: documentation and libraries [Electronic resource]. URL: <https://github.com/hhru/api>.

**Research adviser:** Assoc. Prof. Irina N. Yakovina, Ph.D. in Engineering

**Language adviser:** Assoc. Prof. Gleb V. Toropchin, Ph.D. (Cand. Sc.) in History

### Selecting data to create a dataset for modeling the decision-making process for issuing a consumer loan

**Anastasia Moiseenko**, Novosibirsk State Technical University, Novosibirsk, Russia, [nastkca@mail.ru](mailto:nastkca@mail.ru)

**Alexander Bychkov**, Novosibirsk State Technical University, Novosibirsk, Russia, [sasha.bychkov10@mail.ru](mailto:sasha.bychkov10@mail.ru)

**Abstract:** *The article is devoted to the study of existing models and the selection of characteristics on the basis of which a decision will be made in the authors' model, which will automate the decision process on granting loans.*

**Keywords:** *decision making, loan approval, credit risk, model.*

Not all banks have an effective and objective system for assessing the creditworthiness of borrowers. By modeling the decision-making process for granting a loan, it is possible to reduce the influence of subjective factors and establish more objective criteria for evaluating loan applications.

The lending process is inextricably linked with the action of many risk factors that can lead to complete or partial failure to repay the loan on time. The main factors influencing the occurrence of credit risk in the consumer lending system, which are directly related to the borrower client, are: the professional status of the client, solvency and availability of loan collateral [1]. By considering the existing credit risk factors for consumer loans, it is possible to determine which customer data should be taken into account when deciding whether to issue a loan in order to minimize risks.

The authors reviewed some existing studies by modeling the loan approval process, such as: forecasting customer creditworthiness based on machine learning methods, and building a neural network model of credit scoring [2, 3].

The study of machine learning methods used a set of 20 characteristics describing each borrower: current account status; credit history; average balance on the savings account; place of employment; marital status; permanent residence; property data, etc. The best forecasting result was achieved using a full set of initial factors [2]. However, the process of collecting all of the above data from customers can be time-consuming, if they require documentary confirmation, or inaccurate if banking organizations will base decisions on the responses of potential borrowers.

When building a neural network model of credit scoring, the following input data were used: socio-economic (gender, age, marital status, work experience and place of employment, dependants, personal and family income as a whole, availability of deposits and their amount); information about the loan; credit history [3].

Based on the constructed artificial neural networks, the key factors that have the greatest impact on the “reliability” of the borrower are identified – the borrower’s income and salary.

Based on the studies and data on the sets of factors used, a proprietary set of characteristics was developed, taking into account the results of scientific work [2, 3].

When developing a model for the decision-making process on granting a loan, the following characteristics of potential borrowers will be taken into account: gender, ownership of a car, availability of real estate, number of children, annual income and income category, level of education, marital status, place of residence (rented/private housing).

So, a credit institution needs to have information about the client's salary, as well as the category of his income. Understanding whether the borrower's income is stable, whether it depends on his business activity or is guaranteed will allow you to assess the risks and calculate the number of payments. Information about the availability of a car and real estate is important for securing a loan. The borrower's place of residence (rented \ personal housing) is also important for understanding additional expenses per month, additional income. Data about the client's level of education is also important in assessing risks and understanding professional status. Marital status and the presence of children should be taken into account both to assess risks and to understand the borrower's incentive to repay the loan.

Thus, having the necessary data about the client, it is possible to correctly assess the risks of a consumer loan and make the right decision about its approval or rejection.

#### **References:**

1. Risks in the consumer credit system and ways to regulate them / Starostina S.A. // *Intellect. Innovation. Investment.* - 2017. – № 3. – pp. 52- 56.
2. Shunina Yu. S. Forecasting customer creditworthiness based on machine learning methods / Yu. S. Shunina, V. A. Alekseeva, V. N. Klyachkin // *Finance and Credit.* – 2015. – № 27(651). – pp 2-12.
3. Gusarova O. M. Neural networks in credit scoring / O. M. Gusarova, P. I. Komarov, D. E. Denisov // *Bulletin of the Altai Academy of Economics and Law.* - 2018. – № 5. – pp 107-113.

**Research adviser:** Assoc. Prof. Anna A. Aletdinova, Doctor of Sciences in Economics

**Language adviser:** Assoc. Prof. Dina D. Sin, PhD in geological and mineralogical sciences

### **Utilizing digital footprint technology for planning urban tourist routes: a case study in the Novosibirsk region**

**Ann Shakhova**, Novosibirsk State Technical University, Novosibirsk,  
[shaxova.2023@stud.nstu.ru](mailto:shaxova.2023@stud.nstu.ru)

**Abstract:** *This article discusses the architecture of the service being developed for planning urban tourist routes in the Novosibirsk region using digital trail technology. The aim of this service is to promote domestic tourism among young people by creating a single database of tourist attractions, as well as providing personalized recommendations based on their interests.*

**Keywords:** *service for planning, tourists, digital footprint, domestic tourism.*

In recent years, interest in domestic tourism has been growing in Russia. There are a huge number of attractions in our country, and a lot of information is available about them. This makes it difficult to choose which ones are worth visiting. In this regard, the Internet and social networks have become important sources of information that have a strong impact on the tourism industry and its growth. Today, such a popular direction in the tourism industry as smart tourism is developing. Smart tourism refers to the application of information and communication technologies, such as smart cities, to develop innovative tools and approaches to improve tourism. This includes using smart cities, ICT, mobile communication, cloud computing, artificial intelligence, and virtual reality. In the context of smart tourism, there is a concept called "Analysis of a tourist's digital footprint", which is based on open data analysis and allows you to effectively create a strategy for promoting a tourist destination in a region. This can help identify potential tourists, target specific groups, and show the tourist offer in the region to those interested in it. However, this direction does not imply an offer for certain groups of tourists, which significantly reduces possible tourist trips. This article describes the service being developed for planning urban tourist routes using digital trail technology.

There is a significant amount of published research on the role of recommendation systems and digital footprints in the tourism industry. For example, in the study Abbasi-Mod Z. and Wahdat-Need H. Sadri J [1] described a system for providing recommendations for tourism based on semantic clustering and sentiment analysis. In addition, María Henar Salas-Olmedo, Borja Moya-Gómez, Juan Carlos García-Palomares, Javier Gutiérrez [2], in their article "The digital footprint of

tourists in cities: comparing big data sources", established that several data sources must be used to analyze the presence of tourists in cities.

Despite the large amount of data generated by tourists in cities, the spatial behavior of tourists remains a relatively under-researched area. Therefore, today, the topic of utilizing a digital footprint to plan urban tourist routes still has relevance.

The topic of this study is the description of architecture of a service for planning urban tourist routes using digital trail technology. The service aims to develop domestic tourism in the Novosibirsk region for young people by creating a unified database of tourist attractions in the area and providing personalized recommendations for visitors. The implementation of this project will increase the accessibility of tourist services, discover and explore popular attractions, and increase the interest in less-known sites.

To achieve this goal, the project will utilize digital footprint technology to segment visitors and identify their preferences. The plan is to utilize the Python programming language and the Django framework for programming the server-side of the application. This will allow the creation of personalized recommendations that increase awareness and accessibility of the region's tourism offerings. The project will help develop strategies for promoting current tourism products and determine the need for additional offerings.

Figure 1 illustrates the architecture of the software under development. The user submits their requirements for a route or its features to the system through testing. The system determines the user's category of tourist. Based on this classification, a list of suitable facilities is loaded from the database. The user is provided with information about these facilities, recommendations for visiting them, and the services provided there, as well as any events held there. From this list, the user can create a personalized route. This route is then saved in the database, resulting in a personalized route and booking with a travel company being provided to the user.

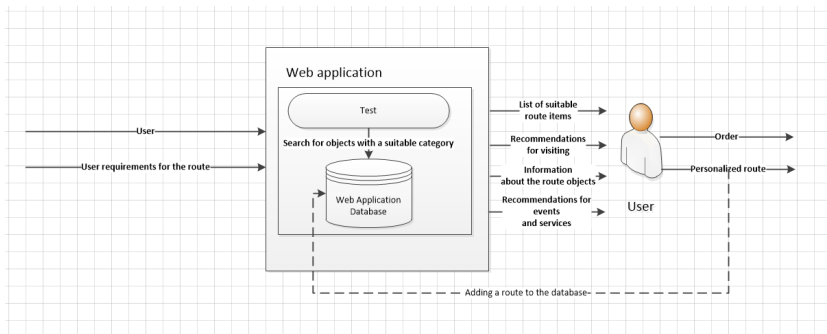


fig. 1 – Architecture of the software being developed

The project will create a unique experience for both domestic and international tourists. Domestic tourists will have an interesting selection of options to choose from, while outbound tourists accustomed to vacationing abroad will also find something unique and appealing. The project will help to improve the index of Novosibirsk's digital presence online, as well as increase the number of visitors to tourist sites.

## References

1. Salas-Olmedo M. H. et al. Tourists' digital footprint in cities: Comparing Big Data sources //Tourism Management. – 2018. – vol. 66. – p. 13-25.
2. Abbasi-Moud Z., Vahdat-Nejad H., Sadri J. Tourism recommendation system based on semantic clustering and sentiment analysis //Expert Systems with Applications. – 2021. – vol. 167. – p. 114324.

**Research adviser:** Kurcheeva, Galina I., Associate Professor, PhD in Economics

**Language adviser:** Getman, Anastasia A., Associate Professor, PhD in Philology

## Advantages and disadvantages of simulation modeling

**Irina Shcherbakova**, Novosibirsk State Technical Universty, Novosibirsk, Russia,

[irina-shbk@mail.ru](mailto:irina-shbk@mail.ru)

**Abstract:** *This article provides an overview of the methods of research and simulation of queuing systems and identifies the disadvantages of using analytical research of such systems. An alternative approach to system modeling and the advantages and disadvantages of this method will be reviewed.*

**Keywords:** *queuing systems (QS), analytical modeling, simulation modeling, experiments.*

Every day we face situations in which there is a need for mass maintenance. In this regard, the issues of analyzing the operation of the QS in order to determine its optimal characteristics become important. For these purposes, there are two approaches to the study of queuing systems that allow you to describe and predict the parameters of their operation – analytical and simulation modeling.

The analytical study of discrete systems involves the use of a variety of mathematical methods that make it possible to obtain the final result explicitly or in the form of mathematical dependencies, the solution of which can be performed by numerical analysis methods. Among the methods for calculating the characteristics of queuing models, the method of averages can be distinguished. Another of the most popular is the method using the Kolmogorov's equations for Markov chains with continuous time.

However, the analytical approach has some disadvantages, which relate to a number of simplifying assumptions regarding the parameters of the incoming flow of applications and the duration of their service.

Known analytical solutions to queuing problems are adequate to the stationary period of the system operation (i.e., the probabilities of system states do not change over time). However, without taking into account the period of non-stationarity, it is impossible to optimize the performance characteristics of the system as a whole, since the transition periods of the system can constitute a significant part of the operating period of the system [1].

The above circumstances call for the use of simulation approaches to modeling.

Simulation modeling is a research method in which the system under study is replaced by a model that describes the real system with sufficient accuracy and allows for the study of this system. In relation to discrete systems with stochastic functioning, this means, first of all, the possibility of studying the properties of systems under any laws of distributions of random variables describing the load.

The use of simulation models provides many advantages, including the following:



- Simulation modeling allows you to conduct experiments with a model, rather than with a real system, which makes it possible to reduce the resources spent on experiments;
- Can be applied to a wide range of systems and processes, and can be used to model various fields;
- Allows you to create realistic models that reflect the actual behavior of the system or process;
- Can be used to predict the behavior of the system in various scenarios and make decisions based on these predictions;
- Allows you to visualize the processes of the system, display its structure and results of work.
  - However, simulation also has a number of disadvantages:
  - Creating detailed and realistic simulation models requires significant time and effort to analyze and design such models, which can be a complex and time-consuming process;
  - The accuracy of the simulation model requires high-quality data for its development and verification depends on the quality and availability of data.
  - The simulation model may contain errors and unspecified factors. That is why, in order to ensure reliability, it is necessary to carefully check and analyze the model.
  - Scaling limitations may occur when modeling large and complex systems. Processing large amounts of data and resources can require significant computing power;
  - Lack of standardization in the field of simulation modeling [2].

Overall, simulation modeling is a powerful tool for analyzing and predicting the behavior of systems and processes. However, before using it, it is necessary to carefully evaluate the advantages and disadvantages and decide whether it is a suitable method for a particular task. When making this decision, it is necessary to compare the expected economic effect with the corresponding estimated costs of using simulation approaches.

## References

1. Aliyev T.I. Fundamentals of modeling discrete systems. / St. Petersburg: St. Petersburg State University ITMO, 2009, S. 363.
2. Borshchev A.V. Practical agent modeling and its place in the arsenal of analytics. / Exponenta Pro: Mathematics in applications, 2004, Nr. 3-4, S. 38-47.

**Research adviser:** Assoc. Prof. Anna A. Aletdinova, Doctor of Sciences in Economics

**Language adviser:** Assoc. Prof. Dina D. Sin, PhD in geological and mineralogical sciences

### **Achieved progress on development of uniqueness controlling software**

**Roman Shevlyakov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
*romanshevly@gmail.com*

***Abstract:** The paper describes the achieved result on the development of software in order to control the uniqueness of student reports. The importance of such software development is mentioned. The main algorithm of work is described. Objectives for the completion of the research are defined.*

***Keywords:** uniqueness, similarity, MinHash algorithm.*

As it was mentioned in [1], student plagiarism remains a widespread practice. Teachers are not always able to control students' independent work. Well-known systems with the common name "Anti-Plagiarism" are commercial developments with a closed source code, so they cannot be customized for local use by teachers in specific cases. That is why during the work on the master's thesis the software was developed with the purpose to control the uniqueness of student reports including the ability to customize the database of papers that are treated as source documents. Other similar developments are not presented as finished software. They are more suitable for studying the phenomenon of plagiarism, determining statistically significant correlations and discussing measures to counteract plagiarism.

The aim of the paper is to describe proposed software with focus on uniqueness controlling. The entire computational task consists of two steps. The main idea of the first step is to specify a database of documents that are treated as the source document. Using a parser program, all the words are collected from such documents. Based on them, metrics are calculated that can determine the structure of the document in numerical equivalent. As soon

as the database is set up, it can be used to directly check suspicious reports. For these reports, a parser program is used in similar manner with metrics computed. Metrics are defined as the average number of words and lines for each of the chapters of the report, and the structure of how the chapters are constructed. Then the most similar reports by metrics values are selected from the database. During the second stage, computational linguistics algorithms are applied to the words from the source reports and the analyzed one. Such algorithms include tokenization, stop word removal, lemmatization, and 3-gram construction. Afterwards, MinHash algorithm is applied to determine the similarity of two documents. This development has been successfully used in the AltaVista search engine [2] for determining the similarity of two *html* (Hyper Text Markup Language) documents. This can also be applied within the context of this task, as it involves working with tokens. This algorithm is applied to all selected original documents with regard to the one being checked. The result is the similarity in percentage of the checked document with each of the selected documents.

The software has practical applications. The designed software allows a teacher to determine the uniqueness of a student report with no manual checking. The saved time can be used in the educational process. Copied papers can be rejected and their authors may be penalized at the discretion of the teacher.

Further work on the software involves the development of a cross-platform application with a graphical interface. Current version runs only on the Linux operating system via command line. This activity will allow the existing development to be prepared for use by teachers.

### References

1. Wilkinson J. Staff and Student Perceptions of Plagiarism and Cheating / International Journal of Teaching and Learning in Higher Education, 2009, vol. 20, p. 98-105.
2. Broder A.Z. On the resemblance and containment of documents / Proceedings. Compression and Complexity of SEQUENCES 1997 (Cat. No.97TB100171), 1997, vol. 1, pp. 21-29.

**Research adviser:** Aleksandr A. Maliavko. Associate Professor, Department of Computer Engineering, NSTU, Ph.D. in Engineering

**Language adviser:** Anastasiya A. Getman. Associate Professor, Department of Foreign Languages for Technical Faculties, NSTU, Ph.D. in Philology

## **Video compression using quantization**

**Pavel Skibin**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[skibin.2023@stud.nstu.ru](mailto:skibin.2023@stud.nstu.ru)

***Abstract:** Quantization is a parameter which most heavily impacts bitrate and distortion of a compressed video. Adaptive quantization can be optimized by modeling dependencies at various levels. This paper proposes using a differential evolution algorithm to assign a quantization parameter during the encoding.*

***Keywords:** compression, quantization, video encoding.*

*With the advent of digital technologies, multimedia content is widely used and distributed for a variety of needs.*

Video data consumes the overwhelming majority of traffic and is forecast to only grow with ultra-high definition video applications becoming more popular in the near future. In order to lessen the burden of video storage and transmission, various video compression techniques are used.

Due to the fact that raw video feed contains an immense amount of data, lossy compression is necessary to transfer the data, and for that, quantization is used. One of the basic parameters that is used to control a video encoding process is the quantization parameter (QP), which defines the quantization step size (QS) for transform coefficients, typically with the goal of matching the available channel bitrate. Adjustment of QP value allows control over the resulting bitrate in a very wide range, from tens of megabits to tens of kilobits per second. Quantization is effectively rounding, the basic operation uses integer division, where QS is the denominator. Consequently, quantization generates distortion: reconstructed signal samples are not identical to original signal samples. Thus, encoders need to solve a rate-distortion optimization problem, maximizing the quality of the video while constrained to a target bitrate. The quantization process can be optimized at various levels of granularity. QS may be adjusted on the frame level, the slice level, the macroblock level, as well as on the coefficient level, and most of the techniques can be combined.

The differential evolution algorithm is an efficient parameter optimization method based on traditional genetic algorithm. It uses real number coding to perform a heuristic random search in a continuous space. However, research that incorporates differential evolution algorithms into the field of video coding is relatively rare, even as differential evolution algorithms are well-suited to optimize a large number of possible coding parameters.

Differential evolution algorithms are initialized with population size, scaling factor, crossover rate, and total number of iterations. The larger the population, the stronger the diversity and the more the search space is expanded, but a large-scale population will inevitably increase the number of evaluations, and in a multidimensional problem, it will increase the time complexity of the entire algorithm exponentially. Scaling factor is used to control the mutation process, a random process performed on selected variables in the population. Crossover rate controls the chance that a new population variable will inherit the attributes of a previously mutated variable.

In order to evaluate the adaptive quantization decision scheme proposed in the paper, the algorithm is compared using the H264 reference software titled Joint Test Model. Preliminary results show a small improvement in the Bjøntegaard Delta rate equal to 4.13%.

### **References**

1. Ahmad, M.F. et al. Differential evolution: A recent review based on state-of-the-art works // Alexandria Engineering Journal.2010. Vol. 39. p. 147–151. doi:10.1016/j.aej. 2021.09.013

**Research adviser:** Assoc. Prof. Ivan N. Tomilov, Candidate of Technical Sciences.

**Language adviser:** Assoc. Prof. Dina D. Sin, PhD in geological and mineralogical sciences.

### **Development of a dataset of syntactic structures for machine translation of Russian sign language**

**Tatyana Vasilchenko**, Novosibirsk State Technical University, Novosibirsk, Russia, [tatyana.vasilchenko.02@mail.ru](mailto:tatyana.vasilchenko.02@mail.ru)

**Abstract:** *The article discusses the process of automating the translation of Russian Sign Language (RSL), paying special attention to the problem of limited data for machine translation of RSL.*

**Keywords:** *sign language, Russian sign language, machine translation, data set, syntax.*

In the modern world, with the increase in communications and the development of machine translation technologies, there is an increasing need for effective translation of various language forms, including sign systems, such as Russian Sign Language (RSL). The number of people with hearing and speech impairments in Russia is estimated from five hundred thousand to several million, and they can be misunderstood both in everyday life and in extreme situations [1].

However, sign language translation is a difficult task due to its specificity. The main problem is that there are currently a limited number of available data sets for Russian Sign Language, and collecting data for machine translation of signs requires the participation of people who can competently perform signs and explain their meanings in a spoken language.

The main difficulty in implementing a computer sign language interpretation system is the quality of translation into Russian Sign Language. By the quality of translation, we understand the correctness of conveying the semantic meaning of a sentence.

As part of the work being carried out, the object of research was considered as a set of connections, relationships and properties between syntactic constructions of the Russian Sign Language, which serve as a source of information for the researcher.

By analyzing the process of developing datasets, the following tools were selected for this work that meet its specifics:

crowdsourcing for data collection, tokenization, text corpora, parallel corpora, video annotation, metrics for assessing the quality of machine translation models, etc.

In order to create a high-quality data set in the future, there is a lot of work to be done to identify key syntactic structures, create an annotated data corpus, develop methods for assessing translation quality, and directly build a machine translation model.

It is expected that the results of this work will significantly improve the communication of deaf and hard of hearing people with the world around them, and will help to expand the possibilities of machine translation into sign languages.

**References:**

1. Slovo and Russian sign language – [Electronic resource] – Access mode. – URL: <https://habr.com/ru/companies/sberdevices/articles/737018/>

**Scientific adviser:** Prof. Mikhail G. Grif, Doctor of Science (Eng.).

**Language adviser:** Assoc. Prof. Dina D. Sin, PhD in geological and mineralogical sciences.

**Software and Systems Analysis of Research on Device and Service Interaction in the Internet of Things Systems**

**Igor Voitsekhovich**, Novosibirsk State Technical University, Novosibirsk, Russia, [igor.voitsekhovich@gmail.com](mailto:igor.voitsekhovich@gmail.com)

***Abstract:** This article explores the role of the Internet of Things (IoT) in the modern world, identifying its potential for enhancing life through device integration and resource optimization. The main focus is to the challenges of interaction in IoT systems and the prospects for their development.*

***Keywords:** Internet of Things, IoT, device interaction, communication, resource management, data security, IoT ecosystems, network infrastructure.*

In the modern world, where technology has become an integral part of our everyday lives, the Internet of Things (IoT) plays a key role by connecting physical objects and electronic devices into a unified information space. This dynamically evolving domain offers us unprecedented opportunities for creating intelligent and interconnected systems. At the center of this evolution is the study of device and service interaction in IoT systems to represent a complex and multifaceted area.

Research into interaction in IoT systems reveals numerous challenges related to ensuring seamless communication, efficient resource management, and data security. From smart homes and cities to industrial enterprises, IoT systems interact with various devices, sensors, and services to form complex ecosystems that optimize our working and living conditions [1].

According to Cisco estimates, 99% of things in the physical world are currently not connected to networks. Therefore, as more and more unconnected devices are connected, the Internet of Things will experience explosive growth.

Within the scope of the research, mechanisms for optimizing resource utilization, such as bandwidth and energy, were examined when devices roam in Wi-Fi networks. Technologies such as Fast Roaming and 802.11k/v/r were studied, along with their impact on energy consumption and network performance. Based on the study, recommendations were proposed for optimizing the use of resources when roaming in Wi-Fi networks [2].

In the future, it is planned to develop algorithms and protocols for fast and efficient switching between access points in Wi-Fi networks for IoT devices. Within this framework, algorithms for optimizing the switching process will be developed, and corresponding protocols for exchanging information between devices and access points will be implemented.

## References

1. Kanis J.A., Oden A., Johansson H., Borgstrom F., Strom O., McCloskey I.V. FRAX – A new tool for the assessment of fracture risk: application in clinical practice and thresholds for intervention. *Osteoporosis and Bone Diseases*. 2012;15(2):38-44.
2. Streamlit – API Reference URL: <https://streamlit-docs.netlify.app/library/api-reference>.

**Scientific adviser:** Assoc. Prof. Dmitry N. Dostovalov, PhD in Engineering.

**Language adviser:** Assoc. Prof. Dina D. Sin, PhD in geological and mineralogical sciences.

## Features of the development of maintenance instructions for an industrial plant using mixed reality technology

**Maxim Denisov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[denisov.00779@gmail.com](mailto:denisov.00779@gmail.com)

**Irina Yakovina**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[yakovina@corp.nstu.ru](mailto:yakovina@corp.nstu.ru)

***Abstract:** The paper discusses the specifics of software development - industrial plant maintenance instructions for Hololens 2 mixed reality device. The tools and platform used, the structure of the software implementation based on the adapted*



*State Machine template are described. The created instruction is a product of immersive learning for training of specialists. The prototype and design of the virtual panel, as well as the operator's work in the application are also briefly described.*

**Keywords:** *mixed reality, application-instruction, HoloLens 2, Unity 3D, State Machine design pattern.*

A few years ago, mixed reality technology began to be used more frequently in various tasks, one of which includes the task of interactive learning. Mixed reality is a part of virtual continuum, where real and virtual objects are presented together on one display. The use of methods and tools realizing mixed reality technology in various subject areas allows to solve the tasks of diagnostics, design and training at a new level.

The customer for the development of maintenance instructions for an industrial plant is Dynamic Models LLC, which carries out projects for large industrial facilities. The wide geography of facilities, different equipment configuration and the need to perform installation and maintenance of equipment requires the company's specialists to quickly adapt to different conditions. Based on mixed reality technologies, the company plans to develop software solutions that will be used to train specialists. One of them is an instruction manual for industrial plant maintenance in the form of an application for the HoloLens 2 mixed reality device.

The paper discusses the main stages of software development for the HoloLens 2 mixed reality device, an industrial plant maintenance manual that can complement the actual employee training process. During the development the following tasks were solved: the selection of tools for creating a mixed reality application; development of the user interface of the application; design and creation of the logic of the software operation; testing and analysis of the obtained results.

**Hardware:** to solve the problem, an application was created for the HoloLens 2 mixed reality device [1-2].

**Software:** the application was developed in Unity 3D using the Mixed reality Toolkit.

*Main virtual panel (interface).* User interaction with the application and influence on the model is done through the main panel. The prototype of the panel is shown in Figure 1a. The main task of such a panel is to provide interaction with the object by the most minimalistic of interaction paths. Minimalism consists in the presence of necessary elements of the panel,

description of the current state and optionally providing additional functions. The panel is a set of buttons and other user interface components.

*Adaptation of the State Machine pattern.* The key idea of the State Machine (SM) pattern is that an object can move from one state to another at any time, given the right conditions. This principle of operation was used in the software part. An abstract SM class was created that keeps track of the current state and runs a pre-specified method when a new state is transitioned. This method of implementation supports state change, stores the current state and divides the logic of operation into separate classes (Fig. 1b).

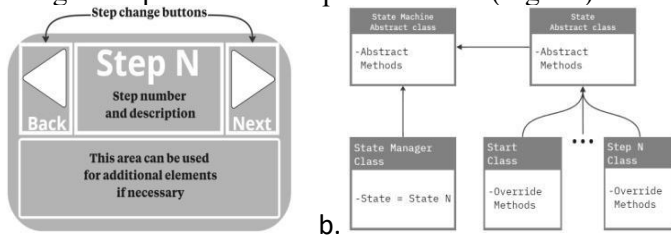


Fig. 1 - Development components: a - prototype of the virtual panel design, b - diagram of the adapted SM template.

During the development of the instructional app, all the above-mentioned tools were utilized in the form of an action scenario. The result was a mixed reality application for the HoloLens 2 device. While working with the application, the operator in the mode of interactive observation of the demonstration of the maintenance process of the industrial plant can interact with its elements (Fig. 2a). It is also possible for the user to interact with the object and its parts (Fig. 2b and 2c).



Fig. 2 - Illustration of work: a - demonstration of operator's work in the developed application - instructions; b,c - user interface windows.

During the development and testing of the mixed reality application the optimal set of tools was formed and the main stages of mixed reality application development were described, the features of the software component of the project, the prototype of the virtual panel design and its implementation were presented. The tested set of tools can be used in the further development of mixed reality applications and in the process of training both future specialists and already trained workers when mastering new equipment and studying scenarios of its maintenance.

### References

1. Microsoft. Manual Mixed Reality, What is mixed reality (2023) [Online] – URL: <https://learn.microsoft.com/en-us/windows/mixed-reality/discover/mixed-reality> (Accessed: 16.02.2023).

2. Microsoft. Manual Hololens, About Hololens 2 (2023). [Online] – URL: <https://learn.microsoft.com/en-us/hololens/hololens2-hardware>(Accessed: 16.02.2023).

**Research adviser:** Yakovina I.N., PhD in Computer Engineering, Associate Professor

**Language adviser:** Getman A.A., PhD in Philology, Associate Professor

### Abstract Title – The System of Analysis and Control of Educational Materials for Plagiarism

**Alexandr Tyvoniak**, Novosibirsk State Technical University, Novosibirsk, Russia, [tyvonyak.2019@stud.nstu.ru](mailto:tyvonyak.2019@stud.nstu.ru)

**Abstract:** *The system of analysis and control of educational materials for plagiarism, which in the academic environment is a serious problem that undermines the foundations of scientific integrity and the quality of education.*

**Keywords:** *plagiarism, machine learning, NLP, control of educational materials.*

The use of machine learning methods in the educational process opens up new opportunities to improve its efficiency and quality. One of the important tasks in this context is the development and implementation of a system for the analysis and control of educational materials for plagiarism. Despite the existence of various software solutions for detecting plagiarism, the

complexity and variety of methods for circumventing these systems require constant improvement of approaches to their development. A feature of the proposed system is the use of advanced machine learning algorithms and language models for text analysis [1].

Plagiarism in the academic environment is a serious problem that undermines the foundations of scientific integrity and the quality of education. The prevalence of plagiarism among students requires educational institutions to implement effective tools to detect and prevent it [2].

Modern machine learning methods, including language models such as BERT and GPT, allow you to analyze large amounts of text data for similarities and plagiarism. The advantage of machine learning is the ability to detect not only obvious plagiarism, but also more complex cases, for example, when the text has been significantly paraphrased.

The proposed system consists of several key components:

- A module for loading and preprocessing text. Clears the text from formatting, breaking it into components for further analysis.
- A module for analyzing the similarity of texts. Uses machine learning algorithms to determine the degree of similarity between texts. It is based on a comparison of semantic and structural characteristics.
- Database of educational materials. It contains an extensive collection of educational and scientific papers for comparison and analysis for plagiarism.
- The user interface. Provides convenient access to the system's functionality for downloading materials and receiving reports on the results of the analysis.

The system can be integrated into the educational process of educational institutions at various levels, providing teachers with a powerful tool for monitoring academic integrity. The use of the system allows not only to identify the facts of plagiarism, but also serves as a preventive measure, reducing the likelihood of its commission by students

To analyze and control educational materials for plagiarism, a variety of machine and deep learning (ML and DL) methods can be used, which provide high accuracy and the ability to process large amounts of data. Here are some of them:

1. NLP (Natural Language Processing) based Methods: TF-IDF, BERT.

2. Semantic analysis: Word2Vec, GloVe, Siamese Networks.
3. Clustering and classification: K-Means, SVM, Random Forests.
4. Deep Learning: CNN, RNN.

The development and implementation of a system for analyzing and monitoring educational materials for plagiarism using machine learning methods is an important step in improving the quality of the educational process. The use of modern technologies makes it possible to effectively combat plagiarism, ensuring academic integrity and maintaining high standards of education.

### References

1. Brian Yu. Harvard, CS50AI: Introduction to Artificial Intelligence with Python, USA, 2024. url: <https://cs50.harvard.edu/ai/2024/notes/6/>
2. Andrew Ng. Advanced Learning Algorithms Stanford. – 2024; URL: <https://www.coursera.org/learn/advanced-learning-algorithms?specialization=machine-learning-introduction>

**Research adviser:** I.N. Yakovina, Cand. Sc in Computer Engineering, Associate Professor.

**Language adviser:** G.V. Igonina, Cand. Sc. in Philosophy, Assoc.Prof.

## POWER ENGINEERING

### **Analysis of transient modeling approaches for data forecasting**

**Sergey Averyanov**, Novosibirsk State Technical University, Novosibirsk, Russia,

[onirs@corp.nstu.ru](mailto:onirs@corp.nstu.ru)

***Abstract:** This article presents a comparative analysis of two approaches to creating mathematical models for forecasting – the “static” approach and the “real-time” approach. The purpose of the analysis is to form an algorithm for modeling the second one.*

***Keywords:** python, relay protection, modeling.*

Protection devices built on a microprocessor basis allow using algorithms for functioning that differ from traditional ones, which are based on new principles of functioning. In the modern segment of software for modeling remote sensing devices, there are quite a small number of software packages that allow you to change the parameters of remote sensing devices and protected objects directly during the modeling process.

The transition process in the energy system depends on many factors. Modeling using static environments such as Simulink requires specifying a number of input parameters that cannot be changed during the simulation process. This fact complicates the assessment of those sources of influence on the energy system that may appear during the transition process, for example, starting the engine at the time of self-starting of other engines, the occurrence of higher harmonic components in the network at the time of engine start. The complexity of modeling lies in the fact that for each consideration of the above-mentioned options for transients, you need to set separate data. Thus, to obtain statistical data, you need to set up a lot of experiments.

The purpose of this work is to analyze approaches to modeling energy models based on the principle of “real time”. The main task is to form a simulation algorithm based on the principle of “real time”.

A real-time model that provides the ability to change the parameters of the transition process without stopping the simulation can be used to increase the speed of modeling, as well as improve the visibility of modeling results [1].

The programming language is considered as a basis, since the language in question has a sufficient number of modern scientific libraries that are constantly updated.

The model consists of a number of functions that simulate the primary equipment of the electrical network. Data are presented as a time series that stores information about instantaneous values of current and voltage in the network. An example is an AC voltage source with a frequency of 50 Hz.

(1)

where there is the value of the voltage amplitude:

- the time value at the moment of a particular iteration;
- iteration counter.

The main data sources for modeling are current and voltage time series obtained in the same way as expression (1). Modeling of various types of events affecting the transient process is carried out by summing the values of the model time series with the values of the event time series. So the resulting time series value is:

(2)

where – current during the transient process:

flag – a flag variable that takes the value 0 or 1, respectively, depending on whether the module is clicked.

The implementation of the switch that controls the transition process is based on graphic blocks that have hotkeys attached to them.

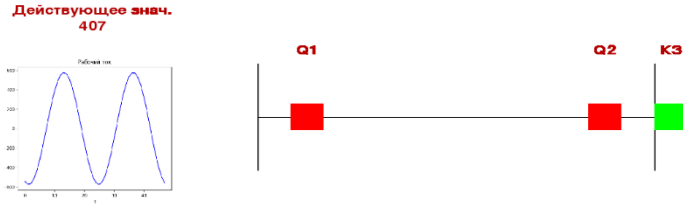


Figure 1-Example of implementing the model's GUI

The main advantage of this modeling approach is the ability to use previous simulated data, for example, a time series of the connection current, including data on the transient process, for predicting current values or recognizing the type of transient process [2]. To implement this, you do not need to create capacious feedbacks, and you can store all the necessary data in a single time series.

So to create a model in Simulink that will use the accumulated statistics to recognize modes, you will need to create a switching schedule, that is, an algorithm for closing and opening switches in certain time periods that are responsible for the component factors of the transition process. According to the schedule, it is necessary to create a model, and then use feedback to submit the received data for input.

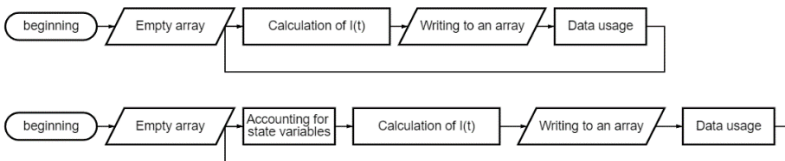


Figure 2-Block diagram of model variants: a) a model with a pre-approved switching schedule; b) a real-time model

Of course, well-known software packages that include various models differ in their accessible interface. However, the real-time modeling method allows you to analyze the impact of external events with the least effort, since it does not require the formation of a switching schedule.

## References

1. 1.H. Li, Z. Wan and H. He, “Real-Time Residential Demand Response”, in IEEE Transactions on Smart Grid, vol. 11, no. 5, pp. 4144-4154, Sept. 2020, doi: 10.1109/TSG.2020.2978061.

2. 2.Chen, J., Zhou, Y., Lin, M., Pan, Z., Ge, J. (2023). A Joint Prediction Method of Multi-State Variables for High-Voltage Cables Based on GRU. In: Yang, Q., Dong, X., Ma, W. (eds) The proceedings of the 10th Frontier Academic Forum of Electrical Engineering (FAFEE2022). FAFEE 2022. Lecture Notes in Electrical Engineering, vol. 1048. Springer, Singapore. [https://doi.org/10.1007/978-981-99-3404-1\\_97](https://doi.org/10.1007/978-981-99-3404-1_97)

**Research adviser:** A.S. Trofimov, Cand. Sc. (Eng.)

**Language adviser:** N.A. Sapchenko, Cand. Sc. (Ped.)

## Development of Modeling Methods for Hydro Turbine Regulators

Alexander Arkhipov, Novosibirsk State Technical University, Novosibirsk, Russia, [sasha00760923@gmail.com](mailto:sasha00760923@gmail.com)

**Abstract:** *This research is aimed at developing methods for modeling and synthesizing hydraulic turbine regulators. The main goal is to increase the efficiency of the hydro turbine regulator. The regulatory process is an important part of managing the technological process of hydroelectric power plants.*

**Keywords:** *LQR-controller, PID-controller, nonlinear dynamic model.*

For efficient operation of the hydroelectric power station, it is necessary to adjust the regulators in such a way that the stability and reliability of the system is ensured. To configure and synthesize control algorithms for automatic control systems of hydraulic units, it is necessary to take into account the nonlinear dynamic characteristics of various components: the main engine, servos, guide device, impeller and torques on the rotor shaft.

In this regard, setting up and optimizing regulators is the most important task for improving the performance of hydroelectric power plants and



reducing the risk of accidents. In the course of the study, the simulation of a hydraulic unit is divided into the following parts:

1. Modeling of the PID-controller;
2. Modeling of the LQR-controller;
3. Performance comparison.

A PID controller is a device used to control processes in industry, engineering, and other fields. It is based on the use of proportional (P), integral (I) and differential (D) control components. The PID controller is usually represented as follows:

$$u(t) = P + I + D = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de}{dt}, \quad (1)$$

where  $K_p$ ,  $K_i$  and  $K_d$  are the gain coefficients of the proportional, integrating, and differentiating components of the controller, respectively.

In this paper, the Ziegler-Nichols method is used to synthesize this regulator. It is based on finding the transfer coefficient ( $K_p$ ) until the stability boundary is reached, after which the value  $K_p^*$  is fixed, indicating a point on the stability boundary, and the period  $T^*$  is measured while using experimental data for studying a system with a P-regulator. [1]

LQR controller is a control method that is used in automatic control systems to stabilize the control object. The main idea of an LQR controller is to minimize the error between the desired and actual state of the control object.

When using the LQR-optimization methodology for solving practical problems, it is important to reliably determine the ratio of the achieved accuracy and the intensity of control functioning, which are represented as two integral terms:

$J_e(K)$  is a functional that characterizes the control accuracy and is represented as follows:

$$J_e(K) = \int_0^{\infty} e' Q e dt = \int_0^{\infty} x' L' Q L x dt; \quad (2)$$

$J_u(K)$  is a functional that characterizes the intensity of control in the process under consideration and is represented as follows:

$$J_u(K) = \int_0^{\infty} u'Rudt; \quad (3)$$

$Q$  is a sign-positive matrix with constant components,  $R$  is a positive definite matrix with constant components,  $c$  is a multiplier that, for given weight matrices, determines the ratio between the accuracy and intensity of control operation in a closed system,  $c = const$  and  $c > 0$ ,  $K$  is a constant matrix of regulator gain coefficients. [2]

To determine the efficiency of the LQR controller, it should be compared to a simulated PID-controller when the load increases. The MATLAB software package will also be used and the results obtained in a single graph will be summarized. As an experimental model, a nonlinear model of a radial-axial turbine was used on the example of units of the Kureyskaya HPP with RO 75/728b turbines. The model was derived by the author in [3].

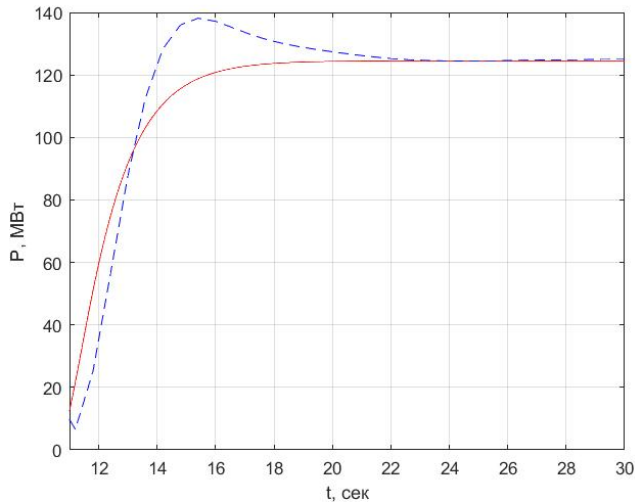


Figure 1 - Graphs of transients of the active power of a hydraulic unit with a stepwise change in the active power reference from 62.5 MW to 125 MW when using the LQRcontroller (solid) and the PIDcontroller (dotted line)

The resulting graph (fig.1) shows that the LQRcontroller has more intensive regulation, as well as less overshoot.

The synthesized LQRcontroller is an effective tool for managing complex systems due to its accuracy, stability and versatility. It also provides fast and stable regulation compared to a PID-controller. Also, the LQR controller allows you to effectively control nonlinear systems, which makes it a more versatile tool for regulation.

### References

1. Denisenko V. V., PID regulators: implementation issues. Part 1 / V. V. Denisenko // Modern automation technologies. - 2007. - No. 4. - p. 86-97.
2. Linear systems with feedback: A textbook. - St. Petersburg: Lan Publishing House, 2013. - 448s.: ill.
3. Kazantsev Yu. V. Issledovanie i razrabotka algoritmov gruppovog regulirovaniya aktivnoy i reaktivnoy moshchnosti GES [Research and development of algorithms for group regulation of active and reactive power of hydroelectric power plants]. Novosibirsk, 2021. – 198 p.

**Research adviser:** Assoc. Prof. Y. V. Kazantsev, Cand. Sc. (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Philol.)

## Measurement of Very Fast Front Overvoltage in Condition of Operated Substations

**Roman Goduntsov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[onirs@corp.nstu.ru](mailto:onirs@corp.nstu.ru)

***Abstract:** This paper presents a comprehensive review of existing techniques for measuring very fast front overvoltages. All methods can be broadly divided into two categories: contact and non-contact. Each approach is analyzed for its advantages and disadvantages, and an optimal method is selected to measure very fast front overvoltages.*

***Keywords:** Very fast front overvoltage, Operation, Non-contact and Contact technique sensors.*

In laboratory conditions and on test-benches, the shape and amplitude of the test voltages can be measured using a capacitive ohmic voltage divider with broadband access. Measurement errors of alternating and switching voltages may also be acceptable when using capacitive voltage dividers. The main requirement of voltage dividers is that, regardless of the frequency or the magnitude of the voltage being measured in the desired ranges, their

division coefficient must not depend on it. In addition, external electrostatic or electromagnetic fields, such as corona discharge, or leakage through the insulating structure of the voltage divider should not affect this coefficient.

In operating conditions, both at substations and on overhead power lines, there are no dividers of either type, and the only way to measure on the power system is through a voltage transformer (electromagnetic or capacitive type). However, these can only measure the first harmonic of alternating current voltage at the industrial frequency with a stated error and an abnormal (though acceptable in practice) error of several harmonics in the main voltage.

For research purposes, it is necessary to record all stages of the transient process, ranging from short (tens to hundreds of nanoseconds) overvoltages to steady-state operating alternating voltages. Broadband voltage measurements are required for this purpose, but laboratory voltage dividers are not designed for outdoor use. Therefore, it is necessary to utilize parts of electrical systems and special sensors at substations and transmission lines to achieve this goal [1].

At present, all existing measurement systems can be divided into two major categories [2]:

- Contact sensor technique;
- Non-contact sensor technique.

The contact methods are based on the formation of voltage dividers that are directly connected to the equipment where the overvoltage is being measured. One such device is a high-voltage input. An insulating terminal may be used as a capacitive voltage divider.

Non-contact sensors are based on the following principle: the electric field in the measured space is proportional to the voltage. It is only necessary to calculate or find the scale factor. The electric field can be considered proportional to the voltage, since the measured space is much shorter than the wavelength of the transient voltage on a high-voltage conductor (1).

$$E_0(t) = k_0 \cdot U_0(t), \quad (1)$$

Where  $k_0$  is the transfer function, which depends on the spatial distribution of the electrical field,  $E_0(t)$  represents the magnitude of the electric field and  $U_0(t)$  is the voltage applied to a high-voltage conductor.

Non-contact measuring systems are more convenient to use compared to contact systems, as they have smaller dimensions and do not require the

measured equipment to be disconnected from the power supply. However, it is necessary to consider the location of the sensor and not move it, as this would require calibration of the scale factor. Accuracy and correctness of measurements may be affected by parasitic capacitances, corona discharges, interference from neighboring overhead lines or electrical equipment, creating an electric field, and other factors.

Table 1 provides brief comparative data of measurement methods.

Table 1 – Comparison of measurement methods

Sensor techniques	The impact of interferences	Bandwidth
Capacitive bushing	-	$\Delta\omega$ (1÷9)MHz
Electric field sensor	+	$\Delta\omega$ 2 MHz
Optical electric field sensor	+	$\Delta\omega$ 500 MHz
Embedded electrode sensor in GIS	+	$\Delta\omega$ 10 MHz
Porthole sensor in GIS	+	$\Delta\omega$ 500 MHz

Based on the analysis of the literature reviewed, it is possible to say that at present there is no specific method for measuring very fast front overvoltages. Most commonly, a high-voltage bushing is used to measure very fast front voltages in operation, as the result is accurate.

When using non-contact methods, it is necessary to eliminate any electromagnetic interference from other electrical equipment in order to obtain accurate measurements. However, there is no need to unplug electrical equipment from the power source.

Additional tests are needed to determine the optimal method for measuring very fast front overvoltage.

## References

1. Ovsyannikov A.G., Voitovich R.A., Lavrov Y.A., Shevchenko S.S., Experience of Switching Surge Measurements in Operating Conditions // ELECTRIC POWER. Transmission and Distribution, 2022. - №2 (71). – P. 98-107. – ISSN 2218-3116
2. CIGRE WG C4.45, Technical Brochure “Measuring techniques and characteristics of fast and very fast transient overvoltages in substations and converter stations”. Reference: 836, June, 2021, ISBN: 978-2-85873-541-9

**Research advisor:** A.G. Ovsyannikov, D.Sc. (Eng.)

**Language advisor:** N.A. Sapchenko, Cand. Sc. (Ped.)

## **Improvement of Algorithms of Operation of Equipment Overload Limitation Automatics**

**Artem Evdokimov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[evdok.tema@mail.ru](mailto:evdok.tema@mail.ru)

***Abstract:** The article deals with the problem of insufficient reliability of existing methods and means of emergency control in electrical systems and grids. The authors emphasize the relevance of the development of new and improvement of existing emergency control equipment in order to increase reliability. In particular, special attention is paid to the improvement of algorithms of the equipment overload limitation automatics. The main difficulties are adequate accounting and modeling of all processes that occur in the power system. Despite this, modern specialized software allows to model power systems with high accuracy. In this paper, the main focus is on improving the algorithms of emergency automation of equipment overload limitation.*

***Key words:** emergency control automatics, equipment overload limitation automatics, modeling of modes, electric power modes.*

The growth of energy consumption in modern society leads to the problem of overloading of transmission lines due to the demand for electricity, which outstrips the rate of development of the energy complex. To solve this problem, automatic equipment overload limitation (AOPO) has been widely used.

AOPO is used to prevent inadmissible in magnitude and duration of current load of controlled elements. The AOPO device shall provide:

- tripping upon detection in any of the three phases of current exceeding the preset value in the controlled element at the current value of the ambient temperature;
- issuing a control action after a preset time delay.

The data on the basis of which the AOPO structure and configuration parameters are selected is provided to the system operator's units by the organization operating the equipment. This data shall contain information on the long-term allowable current for line conductors, line equipment, transformers and autotransformers. For elements with short-term overcurrent

capability, the permissible overload current and the corresponding permissible overload duration are provided [1].

If possible, the AOPO should be performed in such a way that, firstly, the equipment overload capacity is used to the fullest extent possible, and, secondly, excessive realization of control actions is excluded. The level of AOPO perfection depends on the completeness and accuracy of data on equipment overload capacity provided by the operating organization.

The current state of the art makes it possible to realize AOPO algorithms on the basis of microprocessor-based devices possessing a significantly larger spectrum of various control actions than electromechanical analogs. At the same time, at present, due to the possibility of realizing a set of more effective control actions, research in the field of AOPO algorithms improvement is especially relevant.

When developing algorithms of AOPO operation, it is necessary to take into account the conditions of equipment cooling, as one of the main conditions of equipment operation in the overload mode is exceeding the long-term permissible temperature. For example, for an overhead line (OHL) the natural coolant is ambient air. The efficiency of this cooler depends on many time-varying parameters. Therefore, the principle of AOPO operation with an adaptive setpoint is currently predominantly used.

The heating and cooling process of a metal conductor is the basis of the AOPO algorithm using an integral meter. This AOPO algorithm indirectly takes into account the cooling process of the overhead line conductor, is universal and can be used in all microprocessor terminals.

Moreover, at the moment, algorithms for AOPO of facilities operating in extreme weather conditions have been developed, including winter under intensive ice and wind effects and summer under high air temperature limiting power transmission through controlled facilities. Ice accidents caused by the accumulation of ice (frost, wet snow) on wires and lightning protection cables of overhead power lines (OPL) in combination with wind loads are one of the most severe and widespread emergency situations in power systems [2].

To date, algorithms of functioning of overload limitation automatics of overhead power lines with direct control of wire temperature have been developed, taking into account in real time the current climatic conditions to determine the permissible current load of overhead lines. However, due to the

technical complexity of their implementation, these algorithms have not yet been widely used in practice.

Further emphasis of the work will be on trying to improve and implement already available algorithms, for their further practical use.

### References

1. Fundamentals of emergency automation in electric power systems: Textbook / R. A. Vainshtein, E. A. Ponamarev, V. A. Naumov, R. V. Razumov. - Cheboksary: Advertising and publishing center "Promotion of relay protection, automation and control in the electric power industry", 2015. - 182 p.
2. Satsuk, E. I. Software and hardware tools for monitoring overhead power lines and power system control in extreme weather conditions: specialty 05.14.02 "Electric power stations and electric power systems": dissertation abstract Dissertation abstract for the degree of Doctor of Technical Sciences / Satsuk Evgeny Ivanovich. - Novocherkassk, 2011. - 32 p.

**Research adviser:** Assoc. Prof. V. E. Glazyrin, Cand. Sc. (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Philol.)

### Low-Resistance Neutral Grounding In 6-35 kV Networks

**Viktor Zubov**, Novosibirsk State Technical, Novosibirsk, Russia,  
[vitya.zubov.01@mail.ru](mailto:vitya.zubov.01@mail.ru)

**Abstract:** *The study of low impedance grounding mode is an important task for medium voltage class networks (urban power grids). This approach helps to reduce the accident rate of 6-35 kV networks, as well as to ensure reliable power supply to consumers.*

**Key words:** *neutral grounding, single-phase earth faults, medium-voltage cassette network Single-phase earth faults (SPEs) are the most frequent accident in medium-voltage class power networks.*

There are many ways to deal with them, but the main one is the choice of neutral grounding mode. The neutral grounding mode in 6-35 kV networks differs significantly from high-voltage networks by its variability. The main methods of neutral grounding are: – isolated neutral mode: in such networks, the neutral point of the transformer or generator is completely isolated from ground; – resonant neutral grounding: the neutral point of the network is



connected to earth by connecting a special device between these points - an arc suppression reactor; – resistive neutral grounding: the neutral point of the transformer or generator is connected to ground through a high or low impedance resistor; – combined neutral grounding: this method uses a combination of a DGR and a resistor that are connected in parallel with each other between the neutral point of the network and ground.

The benefits and advantages of low impedance neutral grounding are discussed in this research. In general, resistive neutral grounding can effectively limit overvoltages during arc faults (2.4-2.6)  $U_{fmax}$  (first breakdown overvoltage level) and by limiting the fault hold time reduce the negative effects of intermittent arc faults and prevent multiple faults in cable lines and other equipment. One of the main advantages of low impedance neutral grounding is the possibility to realize selective protection against single-phase earth faults, since at resistive neutral grounding in the earth fault current there is an active current component, the value of which is determined by the nominal value of the resistor in the neutral. Also, low impedance neutral grounding allows: – to limit overvoltages during short-circuit faults and reduce the load on equipment insulation; – practically completely eliminate cases of short-circuit with subsequent non-selective emergency disconnection of consumers and equipment damage; – eliminate dangerous ferroresonance processes with damage to voltage transformers; – to build selective relay protection against short-circuit faults on the basis of simple current protections (ANSI 50N/51N) with tripping of only the damaged feeder and reserve input on the 6-35 kV side or on the 0.4 kV side; – minimize the area of damage in case of short-circuit fault due to its fast tripping with reduction of arc burning time; – reduce the time and cost of repairs of electrical equipment damaged by short-circuit faults; – to prevent accidents of electric shock to people and animals; – to reduce the under-supply of electricity to consumers.

Another argument in favor of low impedance neutral grounding is the fact that new cable networks are being designed and built with the widespread use of cables with cross-linked polyethylene insulation. This type of insulation has no self-healing properties. The impact of overvoltages on LDPE insulation leads to the accumulation of defects, which subsequently lead to breakdowns. Therefore, in networks with LDPE-insulated cables, it is

advisable to immediately disconnect a damaged feeder with a single-phase earth fault. As mentioned earlier, low impedance neutral grounding results in an active component of the fault current, which helps the protections to sense and quickly and selectively disconnect the faulted feeder, thus preventing further damage to the network. Thus, low impedance neutral grounding in 6-35 kV networks is an effective way to combat single-phase earth faults. The listed advantages of this type of neutral grounding can ensure reliable power supply to consumers.

#### **References:**

1. Shirkovets, A. Resistive neutral grounding in 6-35 kV networks with SPE cables. Approaches to the resistors selection and principles of building of the overcurrent protection / A. Shirkovets, L. Sarin, M. Ilyinykh, V. Podyachev, A. Shalin // Electrical Engineering News. - №2 (50). - 2008. - URL: <http://news.elteh.ru/arh/2008/50/14.php> (date of address 05.03.2024).

**Research adviser:** Assoc. Prof. A.V. Beloglasov, Cand Sc (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Philol.)

### **Applicability of Normative-Legal Basis for Error Testing of Current Transformers of Classes 10P and 10 PR**

**Viktoria Ilina**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[ilnavv.work@yandex.ru](mailto:ilnavv.work@yandex.ru)

***Abstract:** The paper deals with the issue of applicability of the regulatory framework for error testing of current transformers (CTs) of classes 10P and 10PR. The saturation of the magnetic core of measuring transformers used for protection can lead to distortion of the secondary current and, as a result, to excessive operation or a delay in the operation of the relay protection. Saturation can be caused by residual magnetization and a large aperiodic component. To ensure the reliable operation of transformers, it is important to consider and control these factors, and the accuracy of the current transformation must be in accordance with the set accuracy class.*

***Keywords:** relay protection, current transformer, saturation, accuracy class P, accuracy class PR.*

The saturation of the magnetic core of the measuring current transformers used for protection affects the shape of the secondary current. Distortion of the secondary current in steady-state and especially transient short-circuits modes due to saturation can lead both to excessive operation of relay protection at external short-circuits and to its delay in operation at internal faults.

The causes of the magnetic core saturation are residual magnetisation and aperiodic component. Residual magnetisation can occur when measuring the winding resistance to direct current during testing, as well as under the influence of short-circuit currents during operation of CTs. A large value of aperiodic component is characteristic for networks near generating stations. It should be noted that the aperiodic component is unipolar and even a small value with sufficient duration can lead to saturation of the current transformer core. Therefore, it is necessary to combat the above factors to ensure reliable operation of current transformers or, if it's impossible, to take into account in the implementation of relay protection algorithms connected to the CT.

In steady-state mode, current transformers must meet the accuracy requirements specified in the rules for arrangement of electrical installations. The accuracy of the current transformation is described by the accuracy class of the transformer, which reflects the maximum permissible deviation of the measured secondary current from the predicted one.

GOST 7746-2015 “Current transformers. General technical conditions” makes requirements for secondary windings for protection only for accuracy classes 5P and 10P. This accuracy class does not include requirements for accuracy in transient modes and limitations on residual magnetisation. This means that for current transformers of these accuracy classes is characterized by the presence of residual magnetisation – it can reach more than 80% of the saturation induction.

Reduction of residual magnetisation can be achieved by manufacturing of magnetic cores with non-magnetic gap. This change in the construction of the magnetic core gives an additional effect of linearisation of the magnetisation curve and consequently contributes to the reduction of the residual magnetisation of the current transformer core.

Current transformers with non-magnetic gap have accuracy classes 5PR and 10PR. In accordance with the preliminary national standard PNST 283-

2018 [1], the new accuracy classes of current transformers are characterised by the requirement for residual magnetisation, which should not be more than 10% of the saturation flux. Consequently, when symmetrical short-circuit currents flow, such a current transformer will not go into saturation at the initial moment of failure, and there will be no distortion of the current in the secondary circuit, which will favourably affect the operation of relay protection and automation (RPA). After tripping, the transformer does not require demagnetisation, as the core returns to its pre-short-circuit state when the current in the windings ceases to flow.

From the above, it can be concluded that in most situations the use of transformers with an accuracy class of 5PR or 10PR is recommended to ensure reliable operation of the relay protection system.

However, it is not immediately necessary to replace all transformers of the existing accuracy class P with PR, as this may not be possible or necessary at the moment. If such a replacement is necessary, an error calculation should be carried out in accordance with the requirements of PNST 283-2018 and GOST R 58669-2019 [2], which, however, are intended for transformers of accuracy class P. It is therefore important to consider and evaluate the applicability of the error testing methods prescribed in these standards to transformers of accuracy class PR.

#### **References:**

1. Measuring transformers. Part 2: Specifications for current transformers [Electronic resource]: PNST 283-2018 GOST R. – (<https://docs.cntd.ru>).
2. Unified power system and isolated power systems. Relay protection. Measuring inductive current transformers with closed magnetic core for protection. Methodical guidelines for determining the time to saturation at short circuits [Text]: GOST R 58669-2019. – Vved. 2020-01-01. – Moscow: Standartinform, 2020.

**Research adviser:** Assoc. Prof. A.A. Osintsev, Cand. Sc. (Eng.).

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Phil.).

#### **Peculiarities of Classification of Auto Reclosing Lines**

**Artem Kostoglodov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[toni.kostoglodov@mail.ru](mailto:toni.kostoglodov@mail.ru)

**Abstract:** *The main purpose of the study is to review the classification and performance requirements of automatic reclosing lines to improve the reliability of power supply.*

**Keywords:** *automatic reclosing, rules for arrangement of electrical installations, short circuit, power supply, power line, reliability, voltage.*

Most interruptions and failures of power supply to consumers are caused by short circuits in the elements of the power supply system. Restoration of power supply to consumers, which is lost due to emerging faults on transmission lines, is in most cases carried out by automatic reclosing lines.

The experience of operation of high-voltage networks has shown that the majority of short-circuits caused by insulation overlapping, wire clashing and other reasons are self-corrected by relay protection when the lines are disconnected quickly enough. Such self-avoiding faults are called unstable faults.

The rules for arrangement of electrical installations (PUE) state that auto reclosing can be provided for overhead and mixed (cable-air) lines of all voltage classes above 1 kV.

There are several types of automatic reclosing:

1. Single-phase which, in the event of a single-phase short-circuit, auto recloses one disconnected phase;
2. Three-phase, which auto recloses three phases in the event of a three-phase short-circuit;
3. Combined, which auto recloses both one phase in the event of single-phase faults and three phases in the event of inter-phase faults.

Ensuring the reliability of power supply to consumers also depends on the multiplicity of action of automatic reclosing. In operation automatic reclosing of single and multiple actions are used, where in case of single action reclosing is performed 1 time, and in case of multiple action - 2 or 3 times. The percentage of successful responses on overhead lines of 110 kV and above significantly exceeds the percentage of successful responses on lines of 6-35 kV. The effectiveness of automatic reclosing is due to the instability (self-liquidation) of arc faults [1].

Three-phase reclosing of single lines with single-sided supply in the schemes of in-plant power supply with voltage 0,4 - 10 kV is most widely used at industrial enterprises. Three-phase reclosing of lines with two-way

supply is used for protection of electric networks of external power supply of 35 - 220 kV. While single-phase reclosing is used in inter-system power grids of 220 kV and higher [2].

For lines with one-way supply, the main parameters of reclosing devices ensuring uninterrupted supply are the time delay for reclosing. To ensure reliable operation of the power system, the auto reclosing time must be minimized.

For double-sided lines, automatic reclosing must be carried out after the power supply on both sides has been disconnected.

Despite the large number of types and requirements for automatic reclosing lines, the use of reclosing is one of the main conditions for uninterrupted and reliable supply of consumers.

Future work will be carried out to investigate automatic reclosing more extensively.

### **References**

1. Automation of power systems: textbook for universities. - 3rd edition. corrected / N.I. Ovcharenko; under Ed. Ch. -Corr. RAS, Dr. Techn. Sciences, Prof. A.F. Dyakova. - M. MEI Publishing House, 2009. - 476 p.

2. Ershov, A.M. Relay protection and automation in power supply systems. Part 5: Emergency automation of power supply systems: textbook / A.M. Ershov. - Chelyabinsk: Publishing Centre of SUSU, 2013. – 109 p.

**Research adviser:** Assoc. Prof. A.V. Beloglasov, Cand Sc (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Philol.)

### **Improving the methodology for planning power system operating modes when introducing renewable energy sources**

**Evgeny Kotikov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[kotikoves@gmail.com](mailto:kotikoves@gmail.com)

***Abstract:** In accordance with the Scheme and Program for the Development of Electric Power Systems of Russia, in the south-eastern part of Siberia, by 2029 it is planned to introduce a significant volume of solar generation. To reduce the impact of promising renewable energy sources it is necessary to develop a number of solutions for safe and economical operation of the energy system of the future.*

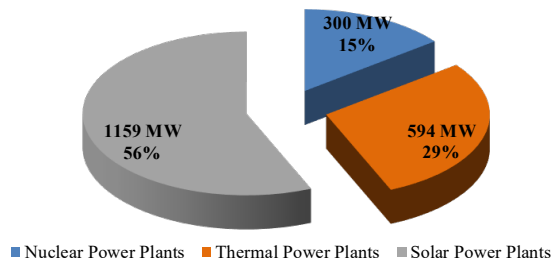
**Key words:** solar power plants, operating modes of the power system, backup of RES with traditional generation, power system of the Trans-Baikal Territory, structure of electricity balances

The purpose of this work is to determine the approaches to forecasting and maintaining operating modes of power systems with a large share of renewable sources, which will mitigate negative impact at the level of generation, transmission and distribution of electricity.

Today in Russia conventional sources dominate, with its own rules of operation that have developed over the years. However, we are on the verge of big changes in the energy mixes: a significant number of renewable energy sources are currently being designed and commissioned. In Siberia, by 2029, it is planned to commission new solar power plants (SPP) with a total installed capacity of 1,159 MW.

Figure 1 shows the structure of the commissioning of new capacities in Siberia for the period until 2029. As it can be seen from the diagram, SPP account for 56% of the total volume of commissioned capacity, which is an impressive share even by the standards of Western Europe, where the green transition began much earlier.

The situation will be aggravated by the fact that all this power will be connected to the electric networks of the Republic of Buryatia (100 MW) and the Trans-Baikal Territory (1059 MW) and, when covering the daily load schedule, will displace the conventional sources, among which the majority of non-flexible thermal plants, many of which also have restrictions on thermal power unloading.



*Fig.1 – Forecast for the commissioning of new generation in Siberia for the period up to 2029*

SPP are characterized by unpredictability of operation depending on weather and disturbances in the electrical network. If there are renewable sources of electricity in the energy system, there is a need to back them up with generating units of traditional power plants.

In addition, with a significant share of solar generation in the energy system, there is a need for a sharp increase in electricity production in the evening. This mode requires the presence of a maneuverable reserve in the system or sufficient flows from adjacent power systems.

When integrating a large volume of renewable energy sources, there is a problem of unevenness and difficulty in predicting their operating modes. At the same time, planning errors require a larger volume of power reserves, which entails an increase in the cost of electricity.

By 2029, with the commissioning of the declared volume of SPP, the power systems of the south-eastern part of Siberia will have to fully face all the mentioned problems when designing the development of the electrical network, when predicting the operating modes of the power system, and determining the load necessary to cover the demand, while ensuring trouble-free operation of the network and in many other cases.

In order to identify the necessary actions aimed at optimizing the operation of SPP in terms of mitigating the impact on the operating modes of electrical networks, reliability and stability, as well as improving methods for predicting their operating modes, we modeled the power system of the Trans-Baikal Territory. The model takes into account the planned commissioning of SPP, production schedules of traditional generation, communication lines with the unified energy system of Siberia, as well as all existing restrictions in the electrical network. Currently, calculations are being carried out using the mentioned model, based on the results of which we will formulate specific proposals for predicting and maintaining the operating modes of Trans-Baikal system and neighboring power systems.

## References

1. Scheme and program for the development of electric power systems in Russia for 2024 - 2029, approved by order of the Ministry of Energy of the Russian Federation No. 1095 dated November 30, 2023.

2. V. Kumar, A. S. Pandey and S. K. Sinha, "Grid Integration and Power Quality Issues of Wind and Solar Energy System: A Review," in International Conference on Emerging Trends in Electrical, Electronics and Sustainable Energy Systems (ICETESES-16), Uattar Pradesh, 2016.



**Research adviser:** Assoc. Prof. A.V. Beloglasov, Cand Sc (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Philol.)

## **Development of an algorithm for automatic calculation of distance line protection**

**Alexey Kurtukov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[kurtukov011@mail.ru](mailto:kurtukov011@mail.ru)

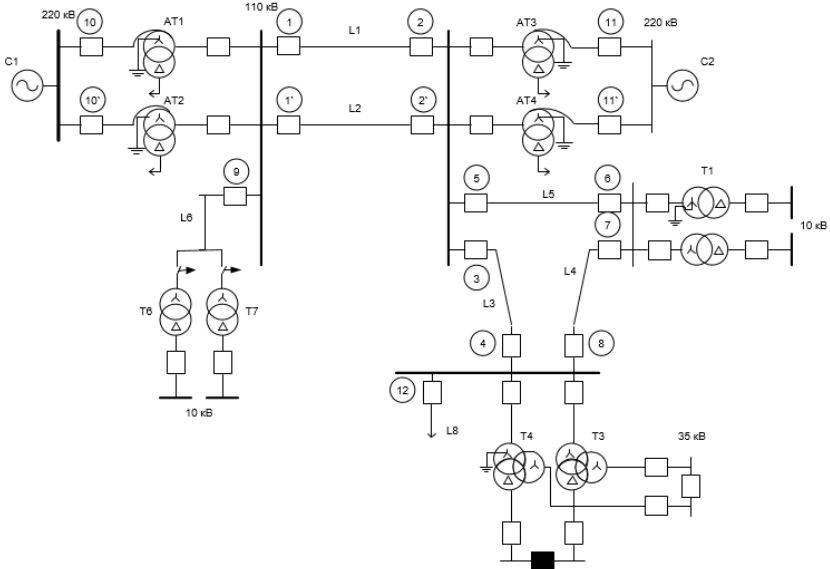
***Abstract:** The paper shows the basic algorithms for calculating distance protection using the traditional method.*

***Keywords:** distance protection, short-circuit, active resistance, reactive resistance, detuning conditions.*

Modern electric power systems are complex structures that provide simultaneous generation, conversion, distribution and supply of electricity to end users. However, both abnormal modes and emergency damages can occur in electric power systems. It becomes necessary to create and apply relay protection and automatics, which protect the system and its elements from dangerous consequences of faults and abnormal modes. As the main protection of 110 kV and 220 kV high voltage lines, distance protection (DP) is used. Distance protection is a universal short-circuit protection. Its principle of operation is based on the measurement and evaluation of the total short-circuit resistance, which, in general, is proportional to the distance from the protection installation site to the short-circuit point. In this work, the resistances and tripping times of distance line protections were selected using the traditional method.

Figure 1 shows a schematic diagram of the electrical network. On its basis, the calculation of distance protection was performed. The first stage was the calculation of the remote protection by reactive resistance, where the resistance of operation of the first stage of the remote protection was selected on the condition of protection against short-circuit at the end of the line. Calculation of the resistance of the second stage of protection was selected from two conditions: coordination with the first stage of protection of adjacent lines, protection against short-circuit on the high side of the transformer. The third stage of distance protection is a backup. It must protect

both its own line and adjacent elements. Therefore, the setpoint of the third stage is calculated from the condition of ensuring sensitivity in the long-distance redundancy mode [1].



**Fig. 1.** Electrical network schematic

The second stage was the calculation of distance protection by active resistance. The tripping resistance of the distance protection by active resistance was selected on the condition of ensuring sensitivity to short-circuits through the arc. For the calculation of the first and second stages of short-circuit protection, a short-circuit on the busbars of the opposite substation was considered. It should be taken into account that the second stage acts to disconnect the damaged object with a time delay, and the arc length by this time has time to increase approximately three times. Calculation of the third stage tripping resistances was performed under the following conditions: we considered modes similar to the modes for which the reactive resistance setpoint of the third stage was selected. The results of calculations of the setpoints of the relay are shown in Table 1.

Комплект	1(1')	2 (2')	3	5	7	8
$X_{y}^I, \text{OM}$	2,76	2,76	1,03	0,78	0,41	0,41
$X_{y}^{II}, \text{OM}$	4,29	4,05	1,95	1,18	0,73	2,91
$X_{y}^{III}, \text{OM}$	34,46	38,32	12,15	9,88	10,25	12,86
$R_{y}^I, \text{OM}$			06	043	05	
$R_{y}^{II}, \text{OM}$						
$R_{y}^{III}, \text{OM}$		17				
$t_{\text{сз}}^{II}, \text{с}$	1	1	1	1	1	0,6
$t_{\text{сз}}^{III}, \text{с}$	3,6	3	2,7	3	2,4	2,1

Table 1 - Calculation results of settings

The results of calculating the sensitivity of the protections showed that the distance protection is suitable as the main protection against phase-to-phase faults.

Thus, we have considered the main stages of calculating the setpoints of relay protection using the traditional method, which in the future will serve as a basis for the construction of an algorithm for automatic calculation.

### References

1. Relay protection of electric networks: textbook / A.I. Scheglov, A.V. Beloglasov. - Novosibirsk: NSTU Publishing House, 2015. - 144 c.

**Research adviser:** Assoc. Prof. A.V. Beloglasov, Cand Sc (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Philol.)

### Review of the existing methods of power quality improving in electric power systems with traction load

Vitaly Less, Novosibirsk State Technical University, Novosibirsk, Russia, [lessv134@gmail.com](mailto:lessv134@gmail.com)

**Abstract:** *The problems and existing research in the field of power quality in electrical networks with traction load are analyzed. Previously developed methods for measuring, analyzing and improving of power quality indicators are reviewed. The analysis of scientific literature allowed us to formulate the relevance and determine the main directions for further research.*

**Keywords:** *traction load, electricity supply, power quality, railways, contact network.*

The railway complex is of particular strategic importance for Russia. It is the connecting link of a unified economic system, ensures the stable operation of industrial enterprises, timely delivery of vital goods to the most remote corners of the country, and is also the most affordable transport for millions of citizens.

The main objective of the research work is to analyze domestic research works devoted to modern methods of increasing and measuring of electrical energy indicators in railway power supply systems.

A significant amount of work has been devoted to the study of power supply systems (SES) of railway transport facilities. The main problems that are raised in scientific works include: increasing the reliability of power supply networks, managing SES modes, improving power quality indicators, increasing the energy efficiency of power supply. In this work, the problems associated with the quality of electrical energy in electrical networks with a traction load were examined in more detail. The relevance of the issue under consideration lies in the fact that a significant part of modern methods for measuring and analyzing power quality indicators in power supply systems is not suitable for use in networks with traction loads. This is due to the design feature of these systems. For example, when an electric train passes through a neutral insert, a short-term interruption of the power supply occurs. When measuring quality metrics, it is difficult to determine whether an interruption is an operating condition or an emergency.

Due to the fact that the power supply system itself is divided into traction and non-traction, there are scientific works that consider each system separately. For example, in article [2] methods for improving the quality of electrical energy only in networks with traction load are analyzed. The main objective of the articles under consideration was the development of methods for utilizing recovery energy within the boundaries of the traction network. Among the methods under consideration are optimizing train schedules, changing the power supply circuit of the contact network (CN), installing parallel connection points, changing the ES system to be the most effective. The use of an interdigitated circuit instead of an interconnected one made it possible to reduce the amount of energy returned to the network by 40%.

It should be noted that the main regulatory document defining measures to improve the quality and reliability of power supply to electric transport in the Russian Federation is the “Strategy for the development of railway transport in the Russian Federation for the period until 2030”. GOST 32144-2013 identifies nine main parameters for assessing the quality of electricity, but article [1] identifies three most important parameters:

1. Frequency deviation in the electrical system;
2. Voltage deviation;
3. Non-sinusoidal voltage.

The article also suggests the ways to improve the quality of electricity according to these three indicators. The problem of the quality of electrical energy is also relevant for non-traction consumers. Deviation from the maximum permissible values of quality indicators has a negative impact on the functionality of railway automation and telemechanics, lighting devices, as well as household appliances in railway buildings. Deterioration of PCE inevitably leads to premature aging and wear of equipment. The percentage of failures of non-traction consumers due to violation of quality indicators is 10-11% of the total amount of failures of these devices.

In the course of the study of scientific literature on this topic, the degree of elaboration of the problem under consideration was revealed. Most of the publications are devoted to such indicators of power quality as voltage deviation in a network with a traction load. However, voltage non-sinusoidality is also a pressing problem in railways. Higher harmonics impair the operation of telemechanical devices and cause malfunctions in their operation. In this regard, one of the objectives of the research work is to develop new methods for improving the quality of electricity in electric power systems with traction loads.

## References

1. Husainov A. R., Semenova N. G. Elektrosnabzhenie zheleznih dorog, puti povysheniya kachestva elektroenergii [Power supply to railways, ways to improve the quality of electricity] // Aktual'nye problem elektroenergetiki [Current problems of the electric power industry]. – Nizhnij Novgorod. 2021g. – S. 292-298.
2. Zagorcev V. A., Terlyakovich S. A. Sposoby uluchsheniya kachestva elektricheskoy energii v sistemah s tyagovoj nagruzkoj [Methods for improving the

quality of electrical energy in systems with traction loads] // Problemy bezopasnosti na transporte [Transportation safety issues]. 2022. T. 1. S. 121-123.

**Research advisor:** D.A. Pavlyuchenko, Ph.D. (Eng.)

**Language advisor:** N.A. Sapchenko, Cand.Sc. (Ped.)

## **A comparative analysis of the Allam cycle and combined cycle power plants**

**Ivan Motyk**, Novosibirsk State Technical University, Novosibirsk, Russia,

[motyk.vanya@yandex.ru](mailto:motyk.vanya@yandex.ru)

**Abstract:** *This article provides a detailed comparative analysis of the Allam Cycle and combined cycle power plants, two innovative technologies aimed at achieving high-efficiency power generation with reduced environmental impact. By evaluating specific efficiency figures, environmental considerations, and economic feasibility, this study aims to offer insights into the potential of these technologies for addressing current energy challenges.*

**Keywords:** *Allam cycle, combined cycle power plants, supercritical carbon dioxide, efficiency, environmental impact, economic feasibility, greenhouse gas emissions, thermal efficiency, scalability.*

The increasing global energy demand coupled with growing environmental concerns necessitates the exploration of efficient and sustainable power generation technologies. The Allam Cycle, utilizing supercritical carbon dioxide (sCO<sub>2</sub>), and combined cycle plants, employing gas and steam turbines, have emerged as frontrunners in this endeavor. This article aims to compare their performance across various parameters.

**Allam Cycle:** Studies indicate that the Allam Cycle can achieve remarkable thermal efficiencies exceeding 59% [1]. By employing sCO<sub>2</sub> in a closed-loop system, this technology shows potential for significant reductions in greenhouse gas emissions, with estimates suggesting up to a 90% decrease compared to conventional natural gas power plants [2].

**Combined Cycle Plants:** Research has demonstrated that combined cycle plants can achieve efficiencies ranging from 50% to 60%. By effectively utilizing exhaust heat from gas turbines to generate steam and drive a secondary turbine, these plants optimize energy utilization, resulting in

reduced fuel consumption and emissions compared to traditional fossil fuel power plants.

Comparison:

1. Efficiency: The Allam Cycle surpasses typical combined cycle plants in thermal efficiency, with figures exceeding 59% [1]. This higher efficiency translates to improved energy conversion and reduced fuel consumption per unit of electricity generated.

2. Environmental Impact: While both technologies offer significant reductions in greenhouse gas emissions, the Allam Cycle demonstrates superior performance due to its closed-loop system and utilization of sCO<sub>2</sub> [2]. Research suggests that it can achieve emissions reductions of up to 90% compared to conventional natural gas power plants.

3. Economic Feasibility: The economic feasibility of the Allam Cycle remains a subject of ongoing debate due to its relatively novel technology and potential scalability challenges. In contrast, combined cycle plants benefit from decades of refinement and widespread deployment, resulting in lower upfront costs and higher confidence in their commercial viability.

Conclusion: In conclusion, the Allam Cycle and combined cycle power plants represent two distinct yet promising approaches to efficient and environmentally sustainable power generation. While the Allam Cycle demonstrates superior efficiency and emissions reductions on paper, its commercial viability and scalability require further exploration. It is still a new and underdeveloped technology, necessitating ongoing research and equipment development. On the other hand, Combined Cycle Gas Turbine (CCGT) plants offer a proven solution with the potential for efficiency improvements by increasing initial steam parameters. These plants have a well-established technology and a proven track record, providing a more immediate solution for meeting current energy needs while mitigating environmental impact. Continued investment and collaboration are essential to harness the full potential of both technologies and pave the way towards a cleaner and more sustainable energy future.

### References:

1. Angelino, Gianfranco, et al. "Design and analysis of a supercritical carbon dioxide cycle for concentrating solar power". *Energy Procedia* 49 (2014): 1622-1631.

2. Brown, L. K. “The Allam Cycle: An opportunity for green power from fossil fuels”. MRS Energy & Sustainability 5 (2018).

**Research adviser:** Assoc. Prof. O.V. Borush, Doc. of Tech. Sci.

**Language adviser:** N.A. Sapchenko, Cand. Sc. (Ped.)

## **Express Limitation of Frequency Reduction And Increase in Local Intelligent Power Systems**

**Mukhammadzhon Odinabekov**, Novosibirsk State Technical University,  
Novosibirsk, Russia, [odinabekov97@mail.ru](mailto:odinabekov97@mail.ru)

***Abstract:** The report is devoted to the issues of preventing shutdowns of generating equipment, in particular, gas piston installations (GPUs) in local intelligent power systems (LIPS) during surges/discharges of active power. The requirements are justified and an algorithm for a special queue (express) of automatic frequency unloading (SQ-AFU) is proposed.*

***Keywords:** LPS, GPU, active power gain/reset, speed, SQ-AFU, algorithm.*

Small generation, mini and microgrids are integrated into existing distribution electric networks or form new electric networks with distributed generation, operating completely or predominantly autonomously. Their peculiarity lies not only in the specifics and variety of the generating equipment used, but also in the inefficiency of using classical technologies and mode control systems.

As a rule, the moment of inertia of low-power power units is small (1-2 s), therefore, electromechanical processes in power plants, including frequency changes during surges/discharges of active power, proceed very quickly. The use of conventional AFU with characteristics suitable for traditional centralized power systems is inefficient [1].

There is an urgent need to quickly (express) limit the decrease/increase in frequency in order to prevent the power plant from being extinguished and to preserve the power supply to consumers.

The research was conducted on the example of a characteristic object, which is a power plant, which is the main source of energy supply to a remote urban neighborhood. At the same time, the real values of the protection settings of the power units of the mini thermal power plant (TPP) with an



electric capacity of 10 MW based on 5 GPUs of 2 MW each of the Berezovoye residential complex in Novosibirsk were used [2].

The requirements for the speed of the AFU automation are determined from the operating conditions of the power plant in the minimum mode (3 out of 5 power units are in operation) and an emergency disturbance in the form of a shutdown of one power unit. According to the n-1 criterion, when operating 3 generators with a nominal capacity of 2 MW, each is loaded by a maximum of 66%. In the event of a sudden shutdown of one of the units, the surge to the remaining generators is 33% of their rated power.

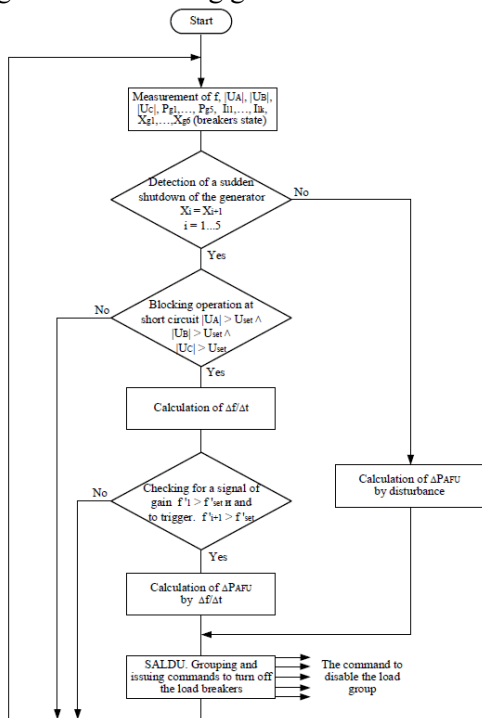


Figure 1 - Algorithm of operation SQ-AFU.

As can be seen from the graph [2], with a power surge of 33%, the response time of the protection of the power unit is 0.1 s and it determines the required speed of the AFU. At the same time, it should be noted that the total

shutdown time of the vacuum circuit breaker is up to 0.05 s, therefore, no more than 0.05 s remains for the operation of the automation of the special AFU queue.

Figure 1 shows the algorithm for working with the AFU, perturbation control and feedback. A certain number of loads are connected to the special automation load disconnection unit (SALDU), and when disconnections occur, the required combination of them is selected and implemented.

In case of short circuits, the operation of the algorithm is blocked, since the voltage ceases to be informative.

The paper presents the results characterizing the features of AFU in local intelligent power systems and the possibilities of its implementation. The AFU should have special queues in its composition, acting both on the fact of power unit shutdowns (perturbation) and on the derivative of the frequency (with feedback).

For the implementation of adaptive algorithms SQ-AFU at a specific facility, a centralized AFU structure with two locations (at the power plant and at the distribution point of the power distribution scheme) is recommended.

### **References**

1. A.B. Osaka, D.A. Panasetsky, E.Ya. Buzina. Intelligent emergency management, taking into account the operating modes of consumers // Bulletin of the IrSTU. – 2017. – Volume 21. – No. 9. – pp. 173-184
2. Odinabekov, M. Z. Investigation of the features of the problem of limiting frequency reduction and increase in local intelligent power systems: master diss.: 04/13/02 – Novosibirsk, 2023. – 79 p.

**Research adviser:** A. G. Fishov, D. Sc. (Eng.)

**Language adviser:** N. A. Sapchenko, Cand. Sc. (Ped.)

### **Control algorithm of the network with small distributed generation based on Large Language Model**

**Ilya Pribilsky**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[\*Pribilvik@mail.ru\*](mailto:Pribilvik@mail.ru)

**Abstract:** *Since networks with small distributed generation (Microgrid) are a technological trend in energy development, the development of control systems for such networks is one of the priorities of EnergyNet. In this regard, this article will present a Microgrid control algorithm based on Large Language Model (LLM).*

**Key words:** *Large Language Model, Microgrid, GPT, Neural Network, control*

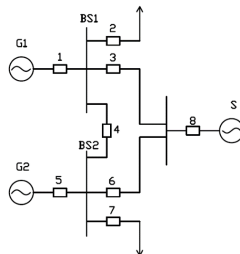
Microgrid is a new approach to energy generation and distribution. But, like any energy system, a network with small distributed generation will tend to constantly expand and become more complex, and create additional subnetworks in it. Such conditions make the use of traditional management methods irrational, since with any change in the scheme or logic of operation, the network owner is faced with the question of reconfiguring existing equipment, or even ordering new one.

This is how the idea of creating a flexible algorithm emerged that could describe in text form any circuit or system control logic.

Next, we will describe in more detail the operation of the proposed control algorithm. The algorithm is based on the use of LLM, in our case we use GPT -4. It is the language model that analyzes the state of the circuit, its parameters and, based on the analysis, issues control actions. LLM receives the description of the power system and control logic from a text file.

The file is called “prompt” and is written in human language. Thus, to specify or make changes to the operating technology, only need is to describe in text format requirements to the model. It is this feature that makes the algorithm truly flexible in configuration.

As an object for testing, a network model with small distributed generation was built in the software Matlab Simulink. The circuit of the simulated network is presented in Figure 1.



*Figure 1 – simulated power system.*

The power system model operates in steady state and sends data about the state of the breakers and the frequency of the bus sections to the LLM. When the frequency changes on one of the buses, LLM analyzes the nature of change and the state of the circuit. The analysis occurs in accordance with the instructions written in the prompt text file. The LLM then sends the corresponding switch outputs to the power system model. In the same way, the model analyzes user commands sent to it, written in text format. The model receives the command, the state of the network and issues control actions. The functional diagram of the model is presented in Figure 2.

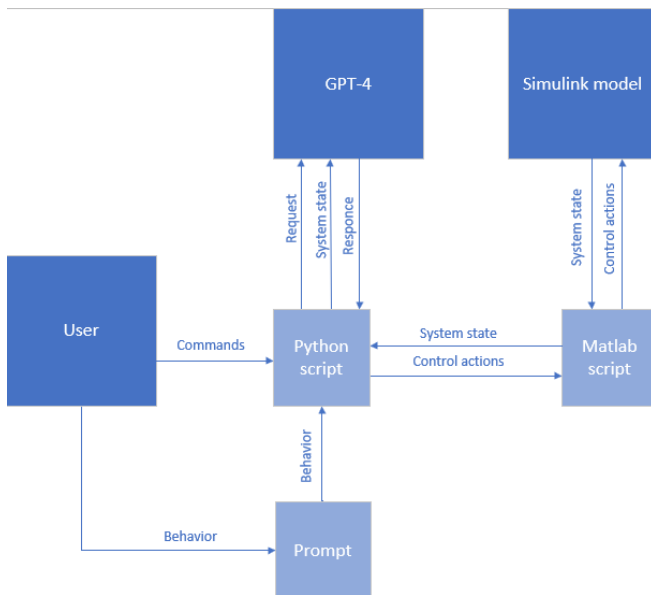


Figure 2 – functional diagram of the model

During the experiments, the execution of user commands by the language and the function automatically adjusted the frequency of the power system in accordance with the instruction algorithms model were tested.

This text presented a network control algorithm with small distributed generation based on the Large Language Model, and also described its

operating principle. During the experiments, promising positive results were achieved, which provide the basis for further development and research.

### References

1. Python docs URL: <https://docs.python.org/3/>
2. OpenAI docs URL: <https://platform.openai.com/docs/overview/>

**Research adviser:** D.V. Armeev, Cand.Sc. (Ped.)

**Language adviser:** N.A. Sapchenko, Cand.Sc. (Ped.)

## **Development of a program for Selection of Emergency Mode Parameters for Testing of OOSP Devices**

**Kirill Seimov**, Novosibirsk State Technical University, Novosibirsk,  
[simbad9984@gmail.com](mailto:simbad9984@gmail.com)

***Abstract:** The out of step protection of remote principle of action is considered in this research paper. The purpose of this study is to optimize the emergency mode parameter selection program for OOSP testing and to develop an algorithm for adapting the emergency mode parameters. Particular attention is paid to obtaining reliable emergency mode hodographs*

***Key words:** OOSP, asynchronous mode, matlab, RETOM-51.*

Out of step protection (OOSP) is one of the most important types of emergency automation (EA), designed to prevent the development of an emergency situation caused by the violation of stable operation of the power system. In general, OOSP can be built on different principles of operation: current, remote and angular OOSP. Also, the relevance of this topic lies in the fact that the selection of emergency mode parameters is a labor-intensive and time-consuming process.

In this paper, the program for selecting emergency mode parameters for testing remote OOSP is considered. The simplest model consisting of several equivalent EMFs of their resistances and the resistance of the line that connects them is taken as a calculation model of the power system [1].

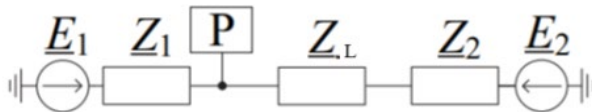


Figure 1 - Computational model of the power system:

$\underline{E}_1, \underline{E}_2$  – vectors of EMFs of equivalent systems C1 and C2, respectively;

$\underline{Z}_1, \underline{Z}_L, \underline{Z}_2$  – are vectors of resistances of systems C1, C2 and line, respectively;

P - place of installation of protection.

The asynchronous mode current was calculated by formula (1.1):

$$I = \left( \frac{(E_1 \angle \varphi_{E_1} - \angle \{ \varphi_{E_2} + 2\pi(t/T_{AX})(1 - \exp(-t/\tau_{AX})) \})}{(Z_1 \angle \varphi_1 + Z_L \angle \varphi_L + Z_2 \angle \varphi_2)} \right) \angle \arg \varphi_1, \quad (1.1)$$

where  $I, \arg \varphi_1$  is the value of asynchronous running current and its angle, at the place of protection installation;  $Z_1, \varphi_1, Z_L, \varphi_L, Z_2, \varphi_2$  are values of resistances and angles of the system "behind the back", of the protected single line, also of the system at the opposite end of the line, respectively;  $T_{AX}$  is the period of the asynchronous stroke, entered in the field with the corresponding name;  $\tau_{AX}$  is  $\tau$  of asynchronous stroke entry, set by the test operator.

To determine the validity of the hodograph with the parameters selected in the program, the hodographs were obtained by oscillography. That is, by loading the parameters of the emergency mode and OOSP organs into the RETOM-51 software and hardware complex.

To recognize asynchronous mode, the device uses asynchronous mode detection (AMD) organs, which are used to analyze the characteristics of the vector's hodograph (trajectory) [2]:

$$\dot{Z}_p = \dot{U}_p / \dot{I}_p, \quad (1.2)$$

where  $\dot{U}_p$  and  $\dot{I}_p$  are complex values of voltage and current measured in the monitored section at the place of installation of the device.

This software product was written in Matlab language using GUI, to facilitate user interaction with the program.

The objectives of the paper were:

- refinement of the program to increase automation;
- obtaining the resistance vector measurement hodograph model;

- obtaining the real hodograph experimentally using the model parameters;
- comparison between simulation-derived and oscilloscope-recorded hodographs.

Also in this paper, assumptions have been used such as:

Line resistance  $Z_L = 0$ ;

Arguments of system resistance vectors  $Z_1, Z_2$  are equal to the angle of maximum sensitivity of the investigated characteristic of the remote-control unit (RCU);

$$\varphi_p = \varphi_{M.S.}$$

All the objectives of this work have been achieved and as a result, an algorithm for adapting the emergency mode parameters for OOSP verification has been obtained. The obtained hodographs of the emergency mode did not fully reflect the reality, because during the study it was found that some simplifications stop working when the center of the trapezoid of the asynchronous mode detection hodographs is shifted from the origin. Since the Matlab program is a language of commercial use, in order to transfer these developments to the personnel operating the equipment with the functions of the OOSP device, it is necessary to transfer this software into the environment of free use. The program will be transferred to the C++ programming language, due to the greater speed and the possibility of integrating the program in this programming language into the RETOM software and hardware complex. Emphasis will be placed on the automation of the selection of emergency mode parameters for OOSP testing.

### References:

1. Frolova E.I. Problema vybora ustavok distancionnoj zashchity kabel'nyh linij / E.I. Frolova // Sbornik nauchnyh trudov Novosibirskogo gosudarstvennogo tekhnicheskogo universiteta. - 2011. – № 1. – S. 113-118.
2. Gonik, Ya. E. Avtomatika likvidacii asinhronnogo rezhima / Ya. E. Gonik, E.S. Igl'ickij. - M.: Energoatomizdat, 1988. - 112 s.: il. - Tekst: neposredstvennyj.

**Research adviser:** Assoc. Prof. A.A. Osintsev, Cand Sc (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Phil.)

## **Construction of a Highly Automated Digital Substation**

**Yuri Sergeev**, Novosibirsk State Technical University, Novosibirsk, Russia,  
*[ignt.r@yandex.ru](mailto:ignt.r@yandex.ru)*

***Abstract:** the main purpose of this work is to develop a technique for building a highly automated educational substation using computer technology and digital means of relay protection and automation.*

***Keywords:** digital substation, “digitalization”, measurements, relay protection*

The electric power system of the Russian Federation includes a large number of different power stations, substations, consumers, as well as electric networks of various voltage classes connecting them. Scientific and technological progress is constantly moving forward, and therefore there is an increase in the number of power consumption. This fact entails the necessary development and expansion of electric networks, an increase in the number of power plants and substations, as well as the introduction of small-scale generation.

Due to the increase in the number of substations, which, most often, are distribution nodes of the power system, it becomes difficult to control electrical installations, account for released electricity, as well as measure voltage, load currents and frequency, since measurements and accounting require the presence of measuring devices at substations, which, overwhelmingly, are analog at substations. Analog devices become obsolete, their measurement error increase, which can lead to an increase in commercial losses. This fact requires verification of devices at substations. Modern problems require modern solutions.

One of these solutions is the introduction of “Digital substations”, where analog control and measurement signals are converted to digital and their transmission is carried out using switches and routers based on data transmission protocols. The “digitalization” of energy will assist in avoiding commercial losses by reducing measurement errors, as well as provide convenience in managing electrical installations at power stations and substations. In addition to providing convenience in the management and accounting of electricity, the “digitalization” of substations will improve relay protection, since without them reliable and safe operation of the entire electric power system is impossible.



Recently, there has been an increase in introduction of digital and microprocessor-based relay protection, gradually replacing relay protection built on an electromechanical basis. Despite its complexity and high cost, microprocessor relay protection is distinguished by its high speed and more accurate tuning conditions that justifies its use at substations. For reliable performance of relay protection, it is necessary to test it, and appropriate specialists are required for this. The main problem lies in the fact that the “digitalization” of energy is a new, little-studied area of development at the moment and requires a high level of training of specialists, since the integration of digital equipment into the electric power system requires in-depth knowledge of both the basics of electrical engineering and information and computer technologies.

**References:**

1. The IEC-61850 standard. Networks and communication systems at substations. Basic communication structure for substations and line equipment. Moscow, Standardinform Publishing House, 2011
2. N.D. Mukhlynin, V.A. Tashilin, Application of IEC 61850 technologies in the electric power industry: lecture notes / N.D. Mukhlynin, V.A. Tashilin, Yekaterinburg: UrFU, 2020. – 213 p.
3. Chernobrov N.V., Relay protection. Textbook for technical schools. 5th edition, revised. and additional M., “Energy”, 1974. – 680 p.

**Research adviser:** Y.V. Kazantsev (Eng.), Cand. of Tech. Sci.

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Phil.)

**Development of the Technique for Calculating Distance Line Protection**

Andrey Sidorov, Novosibirsk State Technical University, Novosibirsk, Russia,

[Sidorov\\_And@mail.ru](mailto:Sidorov_And@mail.ru)

***Abstract:** The main purpose of this paper is to study the operating modes of electrical networks of different configurations and to develop algorithms for selecting the settings of each stage of distance protection, taking into account the verification of all the necessary conditions to form a comprehensive calculation technique.*

***Keywords:** calculation technique, distance protection, algorithms, electrical circuits.*

Distance protection (DP) is a widespread stage protection against phase-to-phase faults with relative selectivity, performed using minimum resistance relays on 35-330 kV lines [1]. Widespread use of relays causes a large number of test conditions when calculating the settings of each stage. In this regard, it is required to propose algorithms for calculation of each stage of the relay with consideration of all necessary test conditions arising in the presence of certain features in the configuration of the network. For this purpose, it is proposed to study the regularities of change in the conditions of calculation of the stages of relay protection on the basis of the analysis of simple electrical networks by their gradual complication (Fig. 1).

Fig. 1A shows the simplest scheme of an electrical network with a single-sided supply. Let us select the remote protection settings for set 1 in accordance with [1]:

$$X_{pt}^I \leq K_o \cdot X_l \quad (1)$$

$$X_{pt}^{II} \leq K_r \cdot \left( X_l + \frac{X_T}{K_{c \max}} \right) \quad K_s = \frac{X_{pt}^{II}}{X_l} > 1,25 \quad (2)$$

$$X_{pt}^{III} \geq K_s \cdot \left( X_l + \frac{X_T}{K_{c \min}} \right), \quad (3)$$

where  $X_{pt}^I$ ,  $X_{pt}^{II}$ ,  $X_{pt}^{III}$  – are setpoints of operation of the corresponding stages;  $K_o$  – adjustment coefficient, it is taken equal to 0,85;  $X_l$  – line resistance;  $K_r$  – reliability coefficient, assumed to be 0,8;  $X_T$  – transformer resistance;  $K_{c \max}$ ,  $K_{c \min}$  – maximum and minimum current distribution coefficients, for this scheme are equal to 1;  $K_s$  – sensitivity coefficient, taken as 1,25.

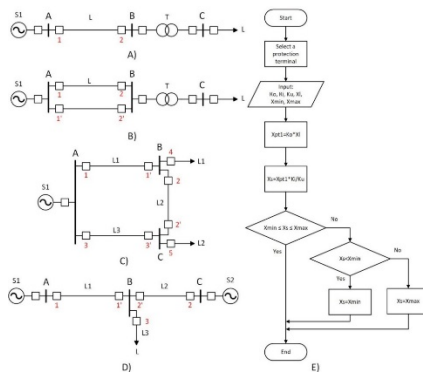


Figure 1 - Investigated schemes of electric networks (A-D) and generated algorithm of calculation of the first stage of distance protection (E)

The scheme in Fig. 2B differs from the previous one by the presence of a double-circuit line, which implies coordination of the line circuit protections for of the second stage of protection in the cascade tripping mode [2]. As a consequence, an additional condition appears:

$$X_{pt-1}^{II} \leq K_r \cdot \left( X_l + \frac{0,9 \cdot X_{pt-2l}^I}{K_c \max} \right) \quad K_s = \frac{X_{pt}^{II}}{l} > 1,25, \quad (4)$$

where  $X_{pt-1}^{II}$ ,  $X_{pt-2l}^I$  – setpoints of the corresponding stages for sets 1 and 2'.

For a ring network with a single-sided supply, shown in Fig. 1C, the installation of directional current protections for sets 1' and 3' is characteristic [1]. The second stage of protection requires coordination with the first stages of outgoing line protections (for example, set 1 requires coordination with the first stage of sets 4 and 2 according to formula (4)) in the open-ring mode. The third stage of protection provides long-distance redundancy and is selected by short-circuit protection on the adjacent feeder, taking into account the current distribution coefficient according to formula (3).

Calculation of setpoints of the circuit with two-way supply (Fig. 1D) is carried out according to the formulae characteristic of the ring circuit (Fig. 1C), taking into account the current distribution coefficient without significant changes.

Based on the results of the study of a number of simple schemes, algorithms for calculation of each stage of distance protection are formed. Let us consider the principle of construction on the example of the algorithm of calculation of the first stage (Fig. 1E). The selection of the protection terminal implies the selection of transformation ratios of current transformers  $K_I$ , voltage transformers  $K_U$ , as well as the limits of the protection tripping setpoints  $X_{min}$  and  $X_{max}$ , entered into the relay protection terminal. After entering the initial data, the setpoint value in the primary circuit is calculated ( $X_{pt1}$ ), then recalculation of the setpoint in the secondary circuit ( $X_s$ ) and then a comparison with the permissible range. If the condition is fulfilled, the setpoint can be entered into the terminal, otherwise the setpoint must be selected from the permissible range: if the setpoint is less than the range, the

minimum possible value for the terminal is taken, if it is greater than the range, the maximum possible value is taken.

The results of the work will be used to form an integral technique for calculating the settings of remote relay protection of lines and to create a program for automated calculations of tripping parameters of its stages.

### References

1. Rukovodjashhie ukazaniya po relejnoj zashhite [Guidelines for relay protection], vyp. 7, Distancionnaja zashhita linij 35-330 kV [Distance protection of 35-330 kV lines], izdatel'stvo «Jenergija», 1966, 175 p. s chert.
2. Shheglov A.I. Relejnaja zashhita elektricheskikh setej [Relay protection of electrical networks]: ucheb. posobie / A.I. Shheglov, A.V. Beloglazov. – Novosibirsk: Izd-vo NSTU, 2015. – 144 p.

**Research advisor:** Assoc. Prof. A.V. Beloglazov, Cand Sc (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Phil.)

### Modelling of a Hydroelectric Power Plant

**Dmitry Sorokopudov**, Novosibirsk State Technical University,  
Novosibirsk, Russia, [dmitrysouth.137@gmail.com](mailto:dmitrysouth.137@gmail.com)

***Abstract:** a nonlinear dynamic model of a hydraulic unit is considered in this article. The aim of the work is to develop and research modern methods of accounting for nonlinear dynamic characteristics to improve the quality of regulation of active power at a hydropower plant. Special attention is paid to the verification of the model obtained and its comparison with the linear model of a hydraulic unit.*

***Keywords:** nonlinear dynamic model, water hammer, rotary-blade turbine, conduit, verification, hydraulic unit.*

Currently, the global electric power industry encounters the problem of the constant growth of contemporary demand for electricity in conditions of limited hydrocarbon fuels. In this regard, hydropower plants are becoming more attractive due to rising fuel prices and the international trend towards the introduction of renewable energy sources (RES)[1]. In modern reality, hydropower plants (HPPs) not only have a low cost of electricity produced, but also participate in covering the maximum load and regulating the balance in the energy system, which becomes especially important when the share of

solar and wind power plants in it increases, characterized by an unstable behavior of the load.

With the integration of the Transient Monitoring System (TMS), fluctuations in active power in the power systems of industrialized countries were revealed. In some cases, this was due to the incorrect functioning of the regulation and control system of hydroelectric power plants, which in turn are related to nonlinear dynamic characteristics [2].

In addition, the paper takes a universal mathematical model of a hydraulic unit with a rotary-blade hydraulic turbine as an object of regulation, which allows to calculate its main output parameters in the modes of load change, start-up and stop.

In the course of the study, the modeling of the hydraulic unit is subdivided into the following parts:

1. Modeling of a conduit;
2. Simulation of a rotary-blade turbine.

The model of the hydraulic unit takes into account the elastic water hammer to connect the dynamic increment of pressure and discharge through the flow path of the turbine, which is a more accurate method of modeling the nonlinearity of the dynamic characteristics of the main propulsion unit.

The main distinguishing feature of a rotary-blade turbine is the ability to change the angle of inclination of the blades for optimal use of the direction of water flow. Therefore, when operating this hydraulic unit, it is possible to adjust not only the opening angle of the guide vane (GV), but also the angle of the hydraulic turbine runner, which affects the efficiency of the installations. The angle of the impeller blades is very important for the optimal functioning of the turbine. With the right angle of rotation of the turbine blades, water will fall on the blades at the right angle, creating the greatest thrust, speed and flow density, which will lead to maximum performance of the turbine.

The specific characteristics are used in the work, which allows to compare the operation of different units on equal terms. Specific characteristics can be shown by following equations:

$$\left\{ \begin{array}{l} n'_i = \frac{nD_1}{\sqrt{H}} \\ Q'_i = \frac{Q}{D_1^2 \sqrt{H}} \\ M'_i = \frac{M}{D_1^3 H} \end{array} \right.$$

where H is the water head, n is the turbine rotation speed, D<sub>1</sub> is the outer diameter of the impeller, M is the torque.

Verification of the nonlinear model and its comparison with the linear model of the hydraulic unit was carried out on the basis of the presented experimental data on Novosibirsk HPP. The check is carried out according to the active power generated by the hydraulic unit in the network.

According to the calculation results, it can be concluded that the nonlinear dynamic model of a rotary-blade turbine coincides with the experimental data on the Novosibirsk HPP with a sufficiently high accuracy, compared with the linear model. In the future, it is planned to conduct additional studies of the behavior of the developed algorithm in emergency mode, as well as further implementation of the hydroelectric unit model based on data from other hydroelectric power plants.

### References:

1. Hydropower flexibility and transmission expansion to support integration of offshore wind/ N. A. Cutululis, H. Farahmand [et al.] // Offshore Wind Farms: Technologies, Design and Operation. – 2016. – Vol. 1 – P. 495-523.;
2. Kazantsev Yu.V. Research and development of algorithms for group regulation of active and reactive power of hydroelectric power plants / Y.V. Kazantsev; Novosibirsk State Technical University. – Novosibirsk: NSTU Publishing House, 2021. - 198 p.

**Research advisor:** Y.V. Kazantsev, Cand. of Tech. Sci.

**Language Advisor:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Phil.)

### Overview of Novosibirsk Thermal Power Stations

Alexander Stepanov, Novosibirsk State Technical University, Novosibirsk,

**Abstract:** *The paper considers the sources of heat supply in Novosibirsk, provides an overview of the city's thermal power plants and shows the possibility of upgrading thermal power plants into dual-fuel combined-cycle gas stations with a parallel operation scheme.*

**Keywords:** *thermal power station, combined cycle gas plant, heat supply, fossil fuel, modernization of the station.*

Novosibirsk is the third largest city in Russia with a population of more than 1.5 million people. The basis of the city's heat supply is thermal power station (TPS) with combined power and heat production, providing 64% of domestic and industrial consumers. The remaining share of the city's heat supply falls on large regional and industrial boiler houses, providing 35% of consumers, as well as 1% of consumers is provided by the mini-TPS of LLC Generation of Siberia [1].

In the previous work, the relevance of the technology of a dual-fuel combined cycle power plants (CCPP) with a parallel operating scheme and its application in the coal regions of Russia, the principle of operation and the basic thermal scheme were considered [2]. The purpose of this article is to review the current state of the Novosibirsk TPS and the possibility of these stations upgrading into dual-fuel CCPPs with a parallel operation scheme. The advantages of the plan upgrading are to increase the efficiency and autonomy of operation, reliability of operation, reduction of emissions into the atmosphere and additional power generation.

As the population grew, the production and consumption of thermal and electric energy in the city increased, that is, new steam boilers, steam turbines, electric generators, transformers, etc. were introduced.

There are four thermal power plants in Novosibirsk (Table 1), of which TPS-2 and TPS-4 operate on Kuznetsk coal, and TPS-3 and TPS-5 on Borodino brown coals [1]. Brief information about thermal power plants is provided below. It can be noted that most of the stations were built in the middle of the last century.

*Table 1 - Novosibirsk thermal power stations*

№	Title	Electric power, MW	Thermal power, Gcal/h	Consumption of natural fuel, thousand tons/year	Input
---	-------	--------------------	-----------------------	---	-------

1	TPS-2	345	920	775	1935
2	TPS-3	496,5	945	1813	1942
3	TPS-4	378,5	1120	974	1952
4	TPS-5	1200	2730	4119	1985

The forecast of the use of organic fuels in thermal power stations is presented (Figure 1) [1].

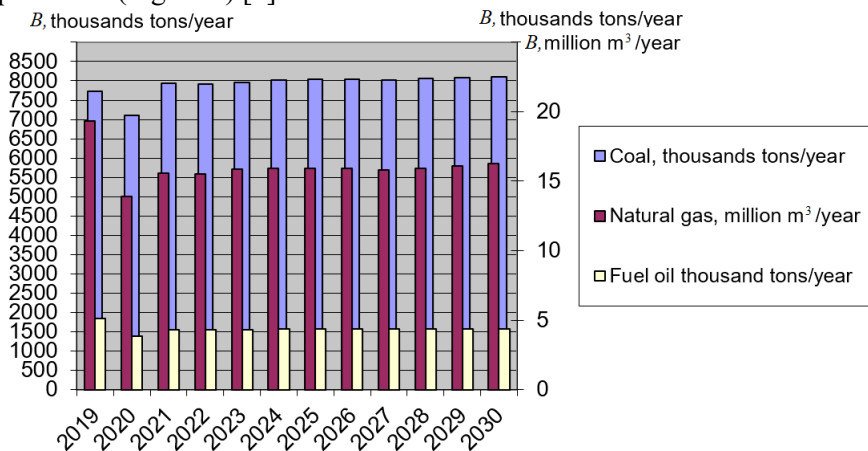


Figure 1 - Forecast of natural fuel consumption at the TPS

Based on forecasts of organic fuel consumption by thermal power plants, it can be concluded that Novosibirsk TPS are not going to abandon burning coal as the main fuel, but on the contrary, its consumption will increase by 5% by 2030 compared to 2019. The consumption of fuel oil remains unchanged during the entire period of time due to the need to use it at the station as a kindling fuel. Natural gas is supplied to each station for the operation of peak hot water boilers, which makes the dual-fuel CCPP technology easier to implement.

At TPS-2, the commissioning of the last steam turbine was completed in 1987, and the steam boiler in 1970 and beyond, only repair and maintenance work was carried out at the station to maintain the operability of the main equipment. The situation is similar with TPS-3 and TPS-4. The last steam boiler with a steam turbine was put into operation at TPS-5 in 2004.

The greatest benefit from the use of parallel-type CCPPs can be obtained in regions with coal-fired thermal power plants that do not plan to abandon solid fuels as the main fuel and at the same time have the opportunity to use



gas. In the Russian Federation, the Siberian and Far Eastern Federal Districts are the most suitable for modernization.

Based on the above, one of the options for improving the efficiency of thermal power plants in Novosibirsk is their modernization into dual-fuel combined-cycle gas stations with a parallel operation scheme by introducing gas turbine installations, waste heat boilers, etc. When using this technology, it is possible to increase the efficiency of a thermal power station from 32 % to 55 %.

### References

1. The scheme of heat supply of the city of Novosibirsk until 2033 (updated for 2023) [Electronic resource]. URL: <http://www.degkh.ru/shema-ts> (date of application: 01.25.2024).

2. Stepanov A.Yu. Review of a two-fuel combined-cycle gas installation with a parallel operation scheme / A.Yu. Stepanov, O.V. Borush; scientific hand. O.V. Borush. – Text: direct // Science. Technologies. Innovations: sat. scientific tr. 17 All-Russian Scientific Conference of Young Scientists, Novosibirsk, 4-8 Dec. 2023: at 11 a.m. – Novosibirsk: Publishing House of NSTU, 2024. – Part 4. – pp. 229-231.

**Research adviser:** O.V. Borush, D. Sc. (Eng.)

**Language adviser:** N.A. Sapchenko, Cand. Sc. (Ped.)

### UV-inspection of External HV Insulation

Nikolay Shvets, Novosibirsk State Technical University, Novosibirsk, Russia,

[shvecz.2011@corp.nstu.ru](mailto:shvecz.2011@corp.nstu.ru)

***Abstract:** The experience in ultraviolet inspection of high-voltage equipment is presented in this paper. The created diagnostic methods of external insulation were based on corona and surface partial discharge characteristics such as space-time distribution and spectral components of light irradiation and also their dependences on voltage value and contamination degree.*

***Keywords:** high voltage, external insulation, corona, surface partial discharge, ultraviolet inspection.*

The presence of corona discharges (CD) and surface partial discharges (SPD) is unacceptable for high-voltage equipment. But in the case of external

insulation, it is impossible to talk about the complete absence of discharge activity, since it is exposed to the environment.

It is noted in [1] that in most cases, a “defect” leading to the occurrence or increase the intensity of discharges has virtually no effect on the main function of the controlled equipment. Really dangerous defects accompanied by discharge processes are:

- 1) flashover porcelain plate insulators in insulator string of overhead lines and substation buses;
- 2) wire throwing onto insulation, conductors and busbars;
- 3) severe contamination of insulation;
- 4) defects in polymer insulators (linear and post);
- 5) cracks on post-rod insulator porcelain insulators.

Thus, it should be noted that the presence of corona on conductors, busbars and conductor fittings has a small effect on the operating condition of the equipment (slightly increases energy losses and radio interference levels) in contrast to the above.

Today, the energy industry uses various types of diagnostic equipment to identify faults and defects on the early stages. For example, ultraviolet flaw detectors are used to obtain discharge patterns (eopograms) and evaluate their intensity on transmission lines and substations.

Corona discharges and surface partial discharges emit light in the UV spectral region. There are various ultraviolet cameras capable of recording discharge phenomena in the UV spectral ranges and combining their images with the image of the equipment.

Different cameras have their own advantages and disadvantages. The solar-blind flaw detector “Filin-6” allows you to see the form of discharge (streamer flashes, corona, etc.), but identifying defects with this device is complicated by the need to work in the dark.

Daytime UV cameras (such as CoroCam, DayCor) are able to detect discharge activity on equipment in good lighting conditions, which is why they are in wide demand. Such cameras mark discharge activity by dots, which does not allow to see the shape of the discharges, and in some cases it is not even possible to unambiguously determine the source of intense discharge activity.

Some solar-blind cameras display on the screen the number of ultraviolet events (photons) of the corona discharge. Some current methodological recommendations, for example in [2], propose criteria for defects based on the number of these events, which in practice leads to false rejection of working equipment.

Thus, the main problem consists of the interpretation of the results obtained by UV-inspection. To solve this problem, the first stage requires updating the normative base and revising the methodology.

### **References**

1. Ovsyannikov A.G., Arbuzov R.S. Ultraviolet inspection: desired and real possibilities // *Energexpert*. – 2020. – No. 2. - P. 14-21.
2. Methodological recommendations for the early detection of defects in external insulation, current-carrying parts of electrical equipment of nuclear power plants using ultraviolet control. MD 1.3.3.99-041-2009. PC “Concern Energoatom”, 2009.

**Research adviser:** A.G Ovsyannikov, D. Sc. (Eng.)

**Language adviser:** N.A. Sapchenko, Cand. Sc. (Ped.)

### **Creation of a Coal-to-gas Switch Estimation Methodology in the Electric Power Generation Sector**

**Pavel Evseenko**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[evs\\_pavel@mail.ru](mailto:evs_pavel@mail.ru)

**Abstract:** *A key goal for the development of the Russian economy is gasification rate increase of Russian regions. It is necessary to create, based on an integrated approach, a coal-to-gas switch estimation methodology for power plants to achieve this purpose.*

**Keywords:** *coal-to-gas switch, fuel mix, indirect effects, integrated approach*

The purpose of this work is to determine the principles and approaches of a coal-to-gas switch estimation methodology creation in the electric power generation sector. This technique will contribute to increasing gasification rate of Russian regions, which in turn will lead to an increase in the standard of living of the population and support the gas industry in conditions of a decrease in Russian gas exports.

To estimate the potential of gasification rate increase of Russian regions, forecast energy mixes are used. Based on the results of energy mix analysis we can observe that the biggest potential gas consumers in Siberia region are heat power plants.

The proportion of coal and gas generation capacity is stable in Siberia region over time (Fig. 1). By contrast there is a trend aimed at coal-to-gas switch in a number of European countries despite they have their own coal reserves but they need to import all using gas [1].

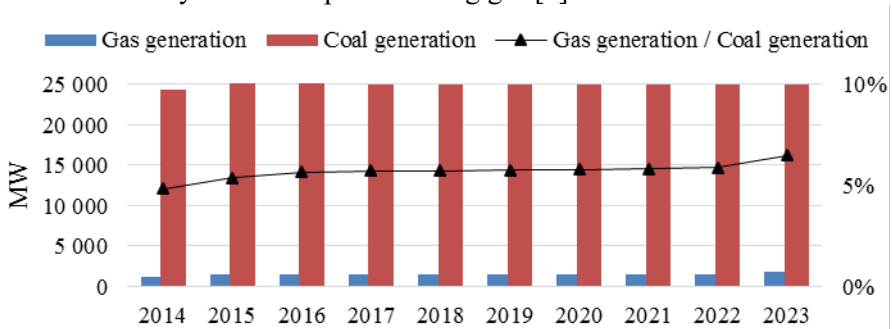
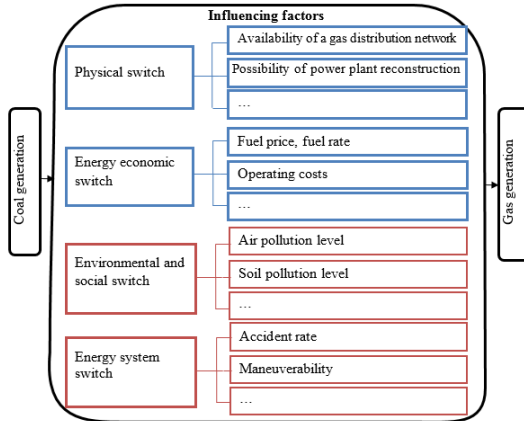


Fig.1 – The historical gas and coal generation capacity in Siberia region

Current forecast energy mix calculation methodology is not optimal in terms of heat power plants coal-to-gas switch potential estimation. It doesn't consider indirect effects of coal-to-gas switch process such as physical, economic, environmental, social and technological (Fig. 2).

It is necessary to create a new methodological approach for a complex estimation of power plants coal-to-gas switch. On date, there are a lot of cases to use an integrated approach in this area in foreign literature [2].



*Fig.2 – Power plant coal-to-gas switch influencing factors*

The clearest and most obvious effects of fuel switching power plants located in big cities are environmental changes and social effects such as: reducing the load on a transport infrastructure using for coal delivery, reducing environmental and health damage associated with a reduction of CO<sub>2</sub> and solid particles emission, abandonment of ash dumps etc.

In addition, it is necessary to estimate indirect effects. For example, if coal storage is removed – the vacated territory (0.3-0.4 hectare per 100 MW) will be able beneficially used and it will bring financial profit, especially if it is located in a big city.

Especially it is necessary to estimate the parameters and working modes of power plants after their fuel switching and influence of this procedure on electric mode and generation mix in a power system. The effect of an accident rate decrease and appropriate rise of energy balance reliability should be estimated. The effect of raising power plant's maneuverability should be also estimated. Maneuverability raising leads to raising of adjusting ability to provide consumers' power load schedule and rising energy efficiency of the generation as a result.

To investigate the indirect effects topic in coal-to-gas power plants switching process integrated approach, regression analysis, neural networks, calculation of electric modes and other types of calculations can be used.

The creation of a coal-to-gas switch estimation methodology for heat power plants allows to raise the inter-fuel substitution calculations (using the energy mix making process in forecast) accuracy and objectivity and provides the increase of Russian regions gasification rate.

To investigate the indirect effects topic in coal-to-gas power plants switching process integrated approach, regression analysis, neural networks, calculation of electric modes and other types of calculations can be used.

The principles and approaches proposed in the article will form the basis for the creation of a coal-to-gas switch estimation methodology for heat power plants, which allows to raise the inter-fuel substitution calculations (using the forecast energy mix making process) accuracy and objectivity and provides the increase of Russian regions gasification rate.

### References

1. Varieties of coal-fired power phase-out across Europe / Gerrit Rentiera, Herman Lelieveldta, Gert Jan Kramerb // Energy Policy 132 (2019) 620–632  
– doi: 10.1016/j.enpol.2019.05.042.
2. Modeling the coal-to-gas switch potentials in the power sector: A case study of China / Hao Chen, Hao-Peng Geng, Hui-Ting Ling, Song Peng, Nan Li, Shiwei Yu, Yi-Ming Wei // Energy, Volume 192, 1 February 2020, 116629  
– doi: 10.1016/j.energy.2019.116629.

**Research adviser:** A.G. Rusina, D.Sc. (Eng.)

**Language adviser:** N.A. Sapchenko, Cand.Sc. (Ped.)

## **Analysis of the development of accidents in a power system with a large share of RES**

**Daniil Kolesnikov**, Novosibirsk State Technical University,  
Novosibirsk, Russia, [i@danekolesnikov.ru](mailto:i@danekolesnikov.ru)

***Abstract:** This study examines an emergency situation that occurred in an electric power network with an integrated source of virtual generation. An analysis of the emergency situation on a section of the power network in Altai was carried out, which led to a disruption of the parameters. Methods for solving this disruption are proposed.*

*Keywords: renewable sources of electricity, distributed generation, inverter, power system stability.*

At the moment, the world is undergoing a so-called energy transition, which includes the widespread use of renewable energy sources (RES). Electricity generation from wind power station, solar power plants and others is being actively introduced into electric power systems (EPS) and distribution networks.

Every year the share of RES in EPS is growing both in the world and in Russia. At the moment, the total installed capacity of RES in Russia has exceeded the threshold of 6.04 GW, including facilities in isolated power systems and industry's own generation. Of this capacity, 97% is made up of RES, which operate in parallel with the centralized network. Although the share of RES in EPS is not large, in some parts of the energy system the share of RES generation exceeds 10%. Which, according to foreign experience, indicates that at this level, the influence of RES on the operation of EPS in the mode of a traditional system can already occur.

However, the integration of RES into existing energy systems causes a number of problems, one of which is the disruption of the stability of the parallel operation of generators in the system under various disturbances in it. After all, RES sources, including electricity storage systems, are connected through semiconductor power converters - inverters, and do not contribute to the overall inertia of the EPS, including the inertial response to disturbances in the network [1]. At the same time, the stability of the EPS directly depends on the reserve of kinetic energy in the generators. Accordingly, the sources connected through inverters do not increase the reserve of kinetic energy of the system, but at the same time they are sources of power [2]. This leads to more severe transient processes in EPS and deterioration of stability conditions during disturbances in them.

The purpose of the study is to analyze the causes of emergency situations in a network with integrated RES and ways to prevent them.

Previously, this problem did not exist, but at the moment, the use of traditional operations can lead to negative consequences. Such as equipment failure, leading to economic losses due to energy that did not reach consumers.

The object of the study is an emergency situation of disruption of regime parameters, which occurred in 2021 in Altai. The study examines the root causes of the disruptions that occurred in EPS with integrated RES. When, during the operational withdrawal of the line for repairs, a section of the power network went into an island isolated mode and had to be switched off. However, immediately after the switch was turned off, the isolated section continued to operate with unacceptable network parameters: frequency and voltage. As a result, the energy district was forcibly de-energized.

The study also examines similar disruptions that have occurred in world practice. So, for example, in Australia there were large-scale accidents in 2016 and 2018, which were accompanied by abrupt changes in the frequency parameters of the mode.

Based on these disruptions, recommendations for ways to solve them are proposed. Including a theoretical consideration of ways to configure network inverters, taking into account the presence of RES in EPS.

It is important to understand that the amount of inertia in the EPS determines the operating mode of the power system, namely, it shapes the nature of the frequency change. As a result of disruptions, a change in the rate of frequency change and the magnitude of its maximum deviation will be observed. As a result, the speed of the transition process occurs faster.

There is also a short circuit ratio (SCR) parameter, which characterizes the network in terms of EPS density. SCR is the ratio of the minimum value of short circuit power at the point of connection of RES to the network without taking into account the influence of RES to the rated power of RES. This parameter must be taken into account when setting up network inverters for RES. This is one of the important factors, because the traditional inverter control system is not always ready for changes in the SCR. And the reasons for changes in the SCR in the network can be very different, for example, shutdown of power lines for various reasons, changes in the composition and power of the load, changes in the composition and power of generating installations, possible inconsistency of electricity generation due to RESs.

The study analyzed the development of this accident when the line was taken out for repair by operating personnel. Possible causes of this disruption of parameters are identified, and methods and recommendations for solving it are proposed.



As a result, this will enable more flexible and reliable operation of RES sources integrated into a traditional centralized network.

### References

1. Burmeister, M. V. Virtual inertia systems: a new approach to the integration of renewable energy sources into electric power systems / M. V. Burmeister, I. I. Berdyshev, R. V. Bulatov, R. R. Nasyrov // *Electricity. Transmission and Distribution*, Moscow. – 2023. – No. 5 (80). – pp. 27-39.

2. Loginov N.A. Study of the dynamic stability of generation sources connected through inverter converters // *Scientific interdisciplinary research*. 2021. No. 3. URL: <https://cyberleninka.ru/article/n/issledovanie-dinamicheskoy-ustoychivosti-istochnikov-generatsii-podklyuchyonnyh-cherez-invertornye-preobrazovateli> (date of access: 03/23/2024).

**Research adviser:** D.V. Armeev, Cand.Sc. (Eng.)

**Language adviser:** N.A. Sapchenko, Cand.Sc. (Ped.)

## MECHATRONICS AND AUTOMATION

### **The research of electromagnetic and hydrodynamic processes during levitational melting of aluminum products**

**Maxim Andreev**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[andreev.maxim.1998@yandex.ru](mailto:andreev.maxim.1998@yandex.ru)

**Abstract:** *This paper deals with the research of electromagnetic and hydrodynamic processes occurring in an induction unit for levitation melting of an aluminum billet weighing 18.6 g. The distributions of current density in the melt, magnetic induction, Lorentz force, and velocities in the melt were obtained.*

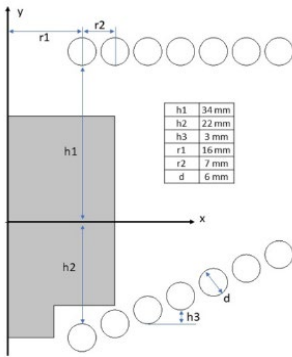
**Keywords:** *alternating electromagnetic field, magnetic hydrodynamics, levitation melting, control volume method, multiphysics.*

There are different methods of aluminum melting: melting in induction crucible and duct furnaces, in resistance furnaces, in gas furnaces. All these types of melting have one significant disadvantage - contamination of the molten metal during interaction with the crucible. This problem can be solved

by melting in suspension. It eliminates contact with the crucible, reduces waste and increases production efficiency.

Suspended melting allows to melt metals and alloys in a vacuum or in an atmosphere of purified inert gas, preserving the purity of the starting materials with the mass content of introduction impurities not exceeding thousandths of a percent. Castings, which are obtained by this method of melting, have high homogeneity and have minimal deviation from the specified alloy composition [1], [2].

Magnetohydrodynamic problems are multiphysics problems. Their peculiarity lies in modeling the interaction of different areas of physics, because of which such problems are often limited by software modeling tools



due to the rather narrow focus and complexity of such problems. Magnetohydrodynamic processes are the processes occurring in a conducting fluid or gas when interacting with a magnetic field. The study of these processes requires synthesis and conjugation of methods of electromagnetism and hydrodynamics. The connecting elements are the inverse effect of fluid motion on its own magnetic field, as well as the force and temperature effects of the electromagnetic field [1], [2].

To investigate the electromagnetic and hydrodynamic processes occurring in the induction system for levitation melting of an aluminum billet weighing 18.6 grams, a numerical model was developed in the Ansys software package, which allows us to calculate the electromagnetic and hydrodynamic parameters of the installation [1], [2].

In this paper, an induction system for levitating melting was considered with the inductor divided into a lower part providing the main levitating force and an upper winding stabilizing the melting in suspension. The calculation scheme is presented in Fig. 1.

In the considered induction system, the effective value of current  $I = 650$  A with frequency  $f = 9650$  Hz is given. The electromagnetic problem is solved by the finite element method.

The hydrodynamic problem is solved in a transient, axisymmetric formulation. An explicit VOF model was chosen taking into account mass forces. The problem involves two Euler phases: air and liquid aluminum.

When solving this MHD problem with feedback, an algorithm was formed:

1. Solving an electromagnetic problem;
2. The volumetric forces  $F(x, y)$  acting on the melt, which were obtained when solving the electromagnetic problem, are unloaded;
3. The unloaded volumetric forces  $F(x, y)$  are interpolated onto the mesh of the hydrodynamic part;
4. Interpolated body forces  $F(x, y)$  are applied on the CFD side of the solver;
5. The hydrodynamic problem is being solved;
6. We unload the volume fraction  $\beta(x, y)$  of the melt obtained by solving the hydrodynamic problem;
7. We interpolate the unloaded volume fraction  $\beta(x, y)$  onto the grid of the electromagnetic part;
8. We apply the interpolated volume fraction  $\beta(x, y)$  on the Emag side of the solver;
9. Repeat the cycle from solving the electromagnetic problem until we reach the required time for solving the problem.

As a result of solving the conjugate MHD problem, the distributions of current density, magnetic induction, Lorentz force and velocity were obtained.

Fig. 2 shows the change in the shape of the free surface over time.

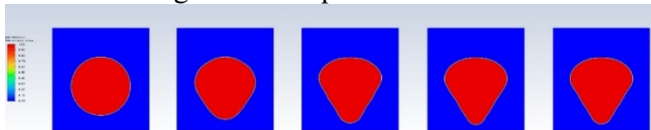


Fig. 2 – Change in the shape of the free surface over time.

Figure 3 shows the results of a similar study by a team of scientists consisting of S. Spitan, E. Baake, B. Nacke and A. Jakovich.

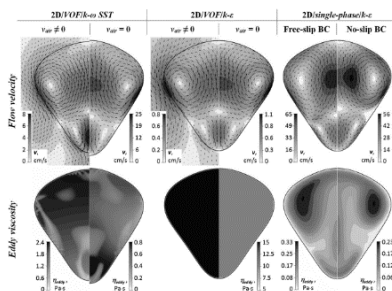
Having analyzed the distributions which were obtained by solving the MHD problem, it can be noted that the shape of the free surface, the velocity field in the melt, the Lorentz force supporting the melt in the air correlate well with the data obtained in the article by S. Spitan [1]-[2], depicted on Fig. 3.

## References

1. S. Spitan, E. Baake, B. Nacke, A. Jakovics, “Numerical Modeling of Free Surface Dynamics of Melt in an Alternate Electromagnetic Field. Part II: Conventional Electromagnetic Levitation, Metallurgical and Materials Transactions,” B, Vol. 47, 2016.

2. S. Spitan, “New technology for large scale electromagnetic levitation melting of metals,” S. Spitan, E. Baake, B. Nacke, A. Jakovics // Magnetohydrodynamics. – 2015. – P. 121-132.

*Fig. 3 – Results of the study by the team of Spitanes, Baake, Nacke and Jakovich [1]-[2].*



**Research adviser:** Morev A.E., Senior Lecturer

**Language adviser:** Igonina G. V., Cand. Sc. (Phil.)

## Development of a shuttle accelerator based on a linear electric motor

Alexandr Trofimenko, Novosibirsk State Technical University, Novosibirsk, Russia, [alex.trofimenko01@inbox.ru](mailto:alex.trofimenko01@inbox.ru)

D. A. Kotin, Novosibirsk State Technical University, Novosibirsk, Russia, [d.kotin@corp.nstu.ru](mailto:d.kotin@corp.nstu.ru)

**Abstract:** the study examines the method of accelerating the weft thread plotter of a loom based on a linear electric motor with elastic elements, including power calculations, evaluation of the mass and dimensional parameters of the electric motor, as well as calculation of springs and torsion bars. Special attention is paid to accelerator modeling and assessment of its transients. The results allow us to

*determine the advantages and disadvantages of this type of accelerator and assess the feasibility of considering this accelerator in the future.*

**Keywords:** *linear electric motor, elastic elements, asynchronous and synchronous motor*

Fabric is one of the most popular materials that is widely used worldwide in various fields of human activity. It is an important component of many items such as clothing, home textiles, furniture, car covers, and industrial materials. Fabric production is a very complex and technologically advanced process that includes many stages that must be performed with high precision and efficiency.

One of the challenges facing Russian weaving industries is the changes in the global economy and the growing competition in the textile industry. Most of the old weaving factories need modernization and improvement of the technical base to increase productivity and product quality.

The purpose of this study is to develop a new type of accelerator for the loom, which will be able to increase the productivity of the fabric. The paper will consider an accelerator based on a linear electric motor with elastic elements [1] and its main characteristics, highlight the advantages and disadvantages of this type of accelerator and describe the prospects for physical implementation.

Setting the tasks:

- 1) Analyze the existing acceleration methods.
- 2) Consider promising technologies for the implementation of the accelerator.
- 3) Calculate the mass and size parameters of an accelerator with a linear electric motor and elastic elements.
- 4) Calculate springs and torsion bars, and select them from those available on the market.
- 5) Estimate the economic costs of producing an accelerator with a linear electric motor and elastic elements.

A linear electric motor of both asynchronous and synchronous types with permanent magnets can be used as a linear propulsion that accelerates the plotter. In subsequent calculations, a synchronous linear electric motor was selected in order to achieve the best weight and size indicators:

Instead of wasting energy on braking the secondary element (RE) of a linear electric motor, it can be stored in elastic mechanical elements, so that it can then be used to accelerate the RE in the opposite direction. This approach can significantly reduce the effort and power of the electric motor, since in this case it is only necessary to cover the power losses that occur in a closed system.

The secondary element (VE) of a linear electric motor has a cylindrical shape and moves inside the primary element, consisting of a fixed magnetic core 5 and a winding 4. When moving from one spring to another, the VE receives acceleration due to interaction with the magnetic field created by the stator winding. Thus, the energy consumed by the winding is spent only on overcoming losses in this system.

Instead of springs, torsion bars can also be used to store the kinetic energy of the RE, while small springs 2 with a low coefficient of stiffness can be added to soften the impact on the RE. Levers 6 connect the springs to the torsion bars.

Based on the reasoning that the efficiency of rotating electric motors of similar dimensions is 80% [2], the efficiency of elastic elements used in this design does not exceed 70%, and taking into account the inevitability of other types of losses in the system, it can be assumed that the total efficiency of the system is approximately 50%.

An electromechanical accelerator based on a linear electric motor with elastic elements is extremely promising for practical implementation, however, the following points should be noted:

- 1) Compression of the spring and torsion torsion does not occur instantly. The time during which the forward and reverse deformation of elastic elements occurs must be calculated and taken into account. At the same time, the mass of the elastic elements themselves must be taken into account, neglecting the nonlinearity of the elastic properties can lead to a significant error in the functioning of the accelerator.

- 2) The considered electromechanical system has its own oscillation frequencies, which must also be taken into account.

- 3) The elastic properties of the elements will change during operation.

- 4) It is necessary to constantly determine the position of the VE.

5) An assessment of the thermal state of the system elements should be carried out and the influence of temperature on their properties should be taken into account.

6) The implementation of an automatic accelerator control system of such a principle of operation will be a rather complex non-trivial science-intensive task.

7) The complexity and multifinality of such a device will require a large number of mock-up and pilot tests, which will be accompanied by significant material costs.

### References

1. Neumann L. A. Linear synchronous electromagnetic impact machines: monograph / L. A. Neumann. – Novosibirsk: NSTU, 2021. – 408 p. – Text: electronic // EBS Lan.

2. A. A. Tatevosyan Optimization of parameters of a low-speed synchronous motor with permanent magnets for a linear drive of a long-stroke single-stage reciprocating compressor / A. A. Tatevosyan. – Text: electronic // News of higher educational institutions. Energy problems. – 2021. – Vol. 23. – No. 6. – pp. 148-156 // NEB eLibrary.

**Research adviser:** Assoc. Prof. D. A. Kotin, Cand. Sc. (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Phil.)

### Magnetic belt accelerator of the weft thread plotter of the loom

Timofey Pridatchenko, Novosibirsk State Technical University, Novosibirsk, Russia, [tigggar@gmail.com](mailto:tigggar@gmail.com)

D. A. Kotin, Novosibirsk State Technical University, Novosibirsk, Russia, [d.kotin@corp.nstu.ru](mailto:d.kotin@corp.nstu.ru)

**Abstract:** *in the course of the study, a computational analysis of various promising types of accelerators was carried out and the best implementation option, namely, a magnetic laser accelerator, was studied in detail. Based on this analysis, a mathematical model of the accelerator was developed and presented. The results show the energy efficiency and prospects of this solution.*

**Keywords:** *magnetic tape accelerator, weft thread plotter accelerator, loom, asynchronous motor (AM).*

A weft thread feed accelerator in a loom is a device used in a loom to feed weft thread quickly and accurately. It regulates the feed rate of the weft thread and its tension, ensuring smooth and stable laying in a row to the main threads and thus increasing the productivity and quality of the fabric.

Due to the termination of the work of foreign manufacturers, Russian enterprises are faced with the need to increase productivity and output.

The main task of the development is to increase productivity and, accordingly, the volume of products produced during a certain working cycle. An important condition is the use of domestic parts to ensure the possibility of integration into existing equipment and repair with minimal costs.

The main device of the accelerator is the supporting frame. Two drives are installed on it and on the tape is put on them. One part of the device for laying a weft thread with magnets is attached to the ribbon and the second, exactly the same part, is attached to the first one. When the engines are started, the laying devices move along the belt. Before entering the weaving zone, the two parts are separated: the upper part passes through the weaving zone together with the weft and, after its completion, reconnects with the other part due to the influence of magnetic forces. Figure 1 shows a diagram of a magnetic tape accelerator and its dimensions:

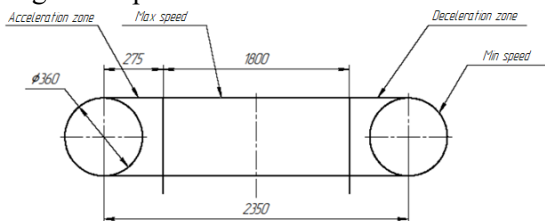


Figure 1 – Diagram of the acceleration device

The calculation of the magnetic system of the plotter is also presented in Figures 2 and 3 [1].

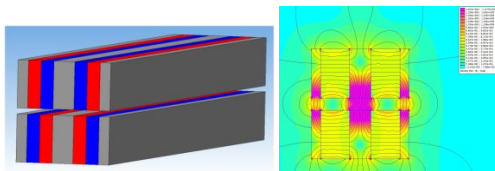




Figure 2 – Model of a modified magnetic system

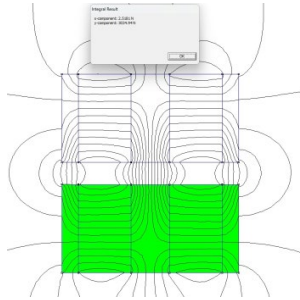


Figure 3 – Calculation of forces acting on a modified magnetic system

To test the magnetic tape accelerator, a simulation model of an electric drive was built. Thanks to her, a full power graph was obtained, shown in Figure 4 [2].

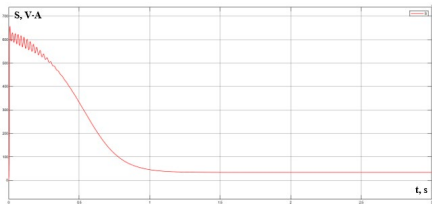


Figure 4 – The full power of the electric drive of the loaded magnetic tape accelerator

Based on the calculations of the system of this accelerator, it can be concluded that it is energy efficient, relative to other accelerator implementation options, since the power consumption in steady-state mode is about 34.4 V·A.

Due to the analysis of various types of accelerators, it can be concluded that the magnetic belt accelerator of the weft thread plotter of the loom proves to be the most effective.

This type of accelerator can be quickly reconfigured to various machine operation parameters using a frequency converter, which is its advantage.

This type of accelerator is easily integrated into the existing loom system due to the weight and dimensions calculated for the dimensions of the machine itself. This allows enterprises to modernize equipment without significant time costs, which contributes to improving the quality and speed of work, as well as increasing the volume of products.

### References

1. Pristup A. G. Modeling of magnetic fields in the FEMM program: textbook.- the method. the manual / A. G. Prikad, A.V. Chervyakov. Novosibirsk: NSTU Publishing House, 2012. 92 p.
2. Pankratov V. V. Adaptive algorithms of sensorless vector control of asynchronous electric drives of lifting and transport mechanisms / V. V. Pankratov, D. A. Kotin. Novosibirsk: NSTU Publishing House, 2012. – pp. 25-26, 123-126.

**Research adviser:** Assoc. Prof. D. A. Kotin, Cand. Sc. (Eng.)

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Cand. Sc. (Phil.)

### Energy efficiency of lithium battery balancers

**Andrei Menschikov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[menshikov1999@yandex.ru](mailto:menshikov1999@yandex.ru)

***Abstract:** The performance of battery balancers is investigated by simulation modeling techniques. A comparison of efficiency of balancer schemes is given, which is relevant for realization of practical problems of energy conservation when using powerful accumulator batteries.*

***Keywords:** balancer, energy efficiency, accumulator battery.*

Lithium batteries are widely used in everyday life and other industries. However, they are delicate to a number of factors that lead to a shortening of their service life and to their damage. One of the main causes of battery life shortening is the imbalance of their charges between the individual cells.

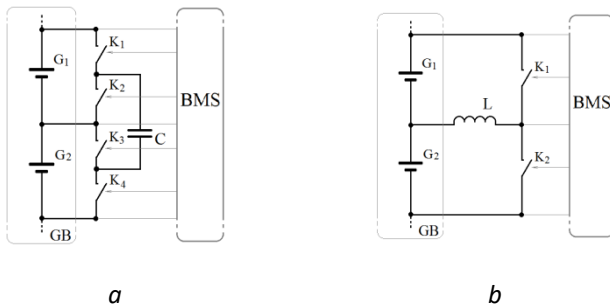
In order to increase the life cycle of a battery, BMS (Battery Management System) is used in practice. The BMS main function is to equalize the charge between all the cells. The purpose of this paper is to compare the energy performance of typical battery charge balancing schemes. The two ways of active balancing will be considered in this paper:

- a) based on a condenser [1];
- б) based on an inductive coil [2].

Active cell balancing (Fig. 1) is based on the idea of transferring energy from cells with excess charge to cells with a deficit of charge. Energy transfer is realized by applying reactive elements: condenser C or inductive coil L.

To simplify the simulation, the analysis of energy characteristics will be considered in balancing of two batteries.

To carry out the simulation of schemes (Fig. 1), it is necessary to determine the parameters of their elements. Condensers of the active balancer (Fig. 1, a), are characterized by the following parameters: nominal capacitance is 2200  $\mu\text{F}$ , whereas ESR (Equivalent Series Resistance) is 60 mOhm. The inductive elements of the active balancer (Fig. 1, b) are characterized by an inductivity of 1  $\mu\text{H}$  and a true resistance of 7 mOhm. A transistor as current-controlled switch has a true resistance of 10 mOhm.



*Fig. 1 - Schemes of typical active balancers: a - based on a condenser; b - based on an inductive coil*

In simulation of the scheme of active balancer based on a condenser (Fig. 2, a), the charge-discharge current at commutation of condenser C in an amplitude is up to 3 A, frequency of commutation is about 500 Hz. The efficiency of the scheme at balancing of two cells is  $\sim 90\%$ .

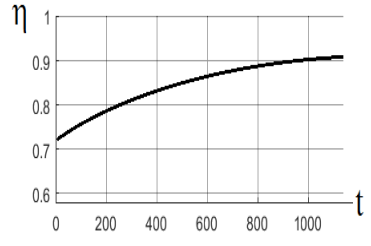
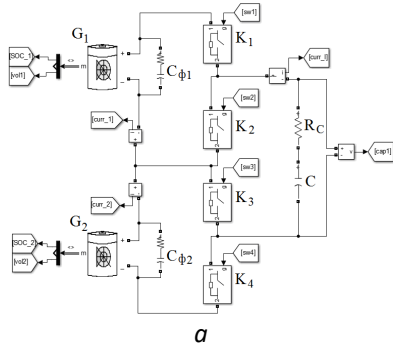


Fig. 2 – A balancer based on a condenser: a – a power part of the scheme; b – change of efficiency in time

Fig. 3, a shows the power part of scheme of a balancer based on an inductive coil. The charge-discharge current at commutation of the inductive element  $L$  is less than the BMS setting of 5 A, frequency of commutation is about 40 kHz. The efficiency of the scheme at balancing of two cells is  $>96\%$ .

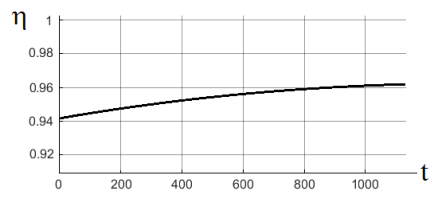
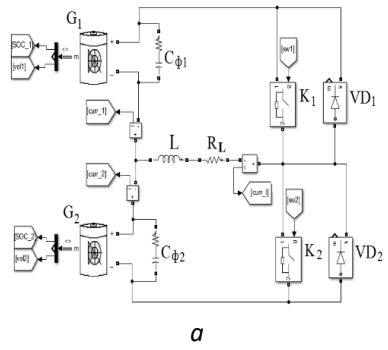


Fig. 3. – A balancer based on an inductive coil: a – a power part of the scheme; b – change of efficiency in time

The active balancer based on an inductive coil has the best performance in equalizing charges between battery cells. Its efficiency is less dependent on the nonuniform distribution of charges in the battery cells and can be up to 95% and higher at operation.

## References

1. Y. Ye, K. W. E. Cheng, Y. C. Fong, X. Xue and J. Lin, “Topology, Modeling, and Design of Switched-Capacitor-Based Cell Balancing Systems and Their Balancing Exploration”, in IEEE Transactions on Power Electronics, vol. 32, no. 6, pp. 4444-4454, June 2017, doi: 10.1109/TPEL.2016.2584925.
2. G. N, G. Yadav and G. CK, “Analysis and Implementation of Inductor Based Active Battery Cell Balancing Topology”, 2020 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), Jaipur, India, 2020, pp. 1-6, doi: 10.1109/PEDES49360.2020.9379358.

**Research adviser:** Myatezh S.V. Ph.D. in Engineering.

**Language adviser:** Toropchin G.V., Ph.D. in History.

## Improving Efficiency of Synchronous Generator with Permanent Magnets

**Anton Fonyakin**, Novosibirsk State Technical University, Novosibirsk,  
[fonyakin2020@mail.ru](mailto:fonyakin2020@mail.ru)

**T.V. Chestyunina**, Novosibirsk State Technical University, Novosibirsk,  
[chestyunina@corp.nstu.ru](mailto:chestyunina@corp.nstu.ru)

***Abstract:** Increased efficiency and reliability of a synchronous generator with permanent magnets is achieved by improving the external characteristics of the generator. The study examines the influence of the permanent magnet location in the rotor and the air gap size on the external characteristics of the synchronous generator at constant power.*

***Keywords:** synchronous generator, permanent magnets, efficiency*

The main characteristic of the generator is the external characteristic, namely, dependence of the output voltage on the current at constant angular velocity of the rotor rotation and the nature of the load. The external characteristic is of great practical importance as it can be used to measure how the voltage at the terminals of the generator changes when its load changes and there is no voltage regulation. The proposed research describes how the electromagnetic calculation was performed and an external characteristic was built for a 30kW synchronous generator with permanent

magnets (SGPM) where magnets are positioned radially on the rotor (Fig. 1) and for SGPM with tangentially positioned magnets (Fig. 2) [1].

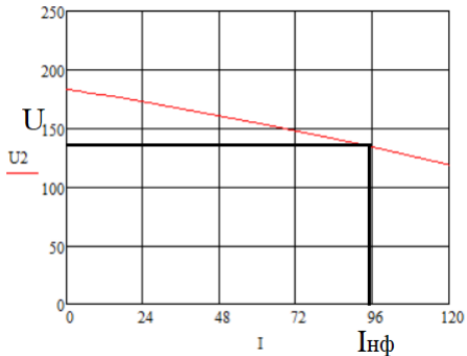


Fig.1. External characteristic for magnets radially positioned on the rotor

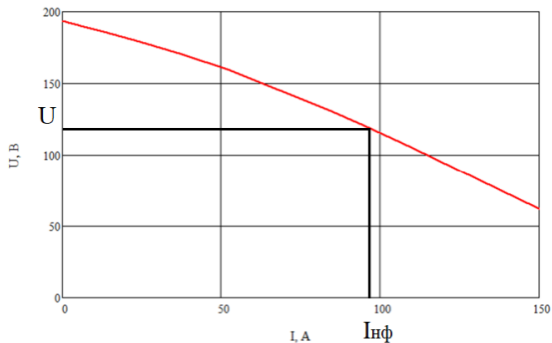


Fig.2. External characteristic for magnets tangentially positioned on the rotor

The external characteristic, which was obtained for SGPM with tangentially positioned magnets on the rotor, has the worst characteristics. The magnitude of the voltage drop is 32.5% (Fig.2). The best result is obtained by the SGPM with radially arranged magnets on the rotor. The magnitude of the voltage drop in this case is 27.5% (Fig.1).

In addition, the effect of the air gap on the magnitude of the voltage drop of the generator was investigated, as well as other indicators at constant power. The results of the study are summarized in Table 1

When calculating the SGPM, the air gap was chosen to be 1 mm. During the experiment, for an air gap of 1.2 mm, a stronger magnet was used: magnet of grade N35SH, residual induction  $B_r = 1.17$  Tl; coercive force  $H_c = 876$  kA/m. And for a smaller gap, that is, 0.6 mm, a weaker magnet was used: N28EH magnet grade, residual induction  $B_r = 1.04$  Tl; coercive force  $H_c = 780$  kA/m [2].

Table 1. Influence of changes in the size of the air gap at constant power

The width of the air gap $\delta$ , mm	Height of magnets h, mm	Voltage drop $\Delta U$ , %	Inductance along the d axis, $X_d$	Inductance along the q, $X_q$ axis	Ph power, kW
0,6	3	30	0.713	0.711	30
1	3	27.5	0.7	0.698	30
1.2	3	26.5	0.673	0.668	30

With an increase in the air gap, the magnitude of the voltage drop decreased, which has a positive effect for the synchronous generator. The maximum value of the air gap in this study corresponds to the minimum value of the voltage drop.

In conclusion, it can be noted that improved efficiency of a synchronous generator directly depends on improving its external characteristics. The characteristic becomes more “rigid” with radially positioned on the rotor, the magnitude of the voltage drop has improved by 5%. Moreover, by changing the size of the air gap, it is possible to improve the most important indicators for the synchronous generator.

## References

1. Shevchenko A.F., Prikad A.G. Electric machines with permanent magnets: textbook - Novosibirsk: Publishing House of NSTU, 2016. – 64 p.

2. Shevchenko A.F., Prikad A.G., Bukhholts Yu.G., Chestyunina T.V., Toporkov D.M., Vyaltsev G.B. Design of electric machines with permanent magnets: a textbook – Novosibirsk: Publishing House of NSTU, 2020. –146 p.

**Research adviser:** T.V. Chestyunina, PhD (Engineering)

**Language adviser:** E.T. Kitova, PhD (Pedagogy)

## **MECHANICAL ENGINEERING**

### **All-terrain vehicle performance calculations**

**Ilya Lanshakov**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[mr.ramzonov@gmail.com](mailto:mr.ramzonov@gmail.com)

**Richard Eyrich**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[richard.eirih@yandex.ru](mailto:richard.eirih@yandex.ru)

***Abstract:** The article is a description of all-terrain vehicle calculation method in various climatic and road conditions.*

***Keywords:** All-terrain vehicle, internal combustion engine, gearbox, tires, difficult overland conditions.*

All-terrain vehicle is a ground vehicle for traveling over rough terrain, in the absence of roads. The all-terrain ability of the vehicle is achieved by using special or combined movers that provide minimum specific pressure on the ground in combination with the maximum possible adhesion on the land. These are wheels with ultra-low pressure tires [1]. The peculiarity of this vehicle is that it moves through the water due to the large displacement of the wheels. Due to the relatively small weight and large volume of wheels, the vehicle is easy to move through snow or swampy terrain.

First, an analysis of the operating conditions of the vehicle is performed. All-wheel drive vehicles are used in a wide variety of climatic conditions. These operating conditions are usually characterized by the following factors: humidity and dustiness of the air, amount and intensity of precipitation, wind speed, altitude above sea level. The temperature factor significantly affects the operation of the all-terrain vehicles. The influence of low temperatures is especially noticeable - the lower the temperature limit of the vehicle's use, the more complex it's design. This is due to the need to introduce auxiliary



systems that ensure the operation reliability of the internal combustion engine, transmission, steering, braking system, suspension, etc., as well as the appropriate working conditions of the driver at low temperatures. In addition, the use of lubricants, rubber products, and, at particularly low temperatures, cold-resistant metals is required [2].

Currently, when designing all-terrain vehicles, the operating range of air temperatures is  $-45...+50$  °C, which corresponds to the operating conditions in temperate zones. A typical combination is very high temperatures (40 °C) with very low humidity (< 30%). High humidity in these zones is possible only at relatively low temperatures. It is the same in other zones: high humidity is observed only at low air temperatures. In this regard, creating all-terrain vehicles provides measures to ensure corrosion resistance for temperate conditions with a maximum relative humidity of 98% at the temperature of 25 °C [2].

Dustiness of the air is one of the most important characteristics of the all-terrain vehicles operating conditions. Usually all-wheel drive vehicles are designed for use on dirt roads and off-road, where increased dustiness occurs in the dry season. The maximum permissible mass concentration of dust which the vehicles must operate for a long time is  $1.5...2.5$  g/m<sup>3</sup>. At these values, the duration of vehicles operation without changing and cleaning the filter elements is set within 12 ... 28 hours [2].

Wind speed and precipitation intensity have a lesser impact on the design of the vehicles, although that requires consideration, mainly in connection with ensuring the thermal operation of the vehicle units (in winter) and appropriate comfort in the cabin.

Altitude is a geographical factor that mainly affects the power of the engine and its thermal regime. This factor depends on the need to overcome long ascents and descents with reduced engine power.

The engine power depends on the density of the air and its temperature – both of these factors depend on the altitude above sea level. As a result of changes in air density, the engine power decreases significantly with increasing altitude. Taking into account the geographical features and the established road network in mountainous areas, the operational requirements provide for the use of all-terrain vehicles on the ground and on roads at the height of mountain sections of no more than 4000 m.

The calculation method includes following parameters:

- total vehicle weight;
- value of the internal combustion engine power;
- internal combustion engine torque;
- specific effective fuel consumption;
- current value of the hourly fuel consumption;
- transmission parameters;
- transfer gears;
- equation of power balance;
- speed of the vehicle in different gears;
- size of the wheel;
- number and type of tires;
- the thickness of the vehicle body;
- assessment of unsinkability of all-terrain vehicle;
- assessment of load conditions;
- sizes of all-terrain vehicle.

## References

1. Snegobolotokhody Khishchnik-3930 [Elektronnyi resurs] Rezhim dostupa: <https://hishnikpro.ru/modelnyy-ryad/hishchnik-3930-1/> (Data obrashcheniia 15.03.2024) [All-terrain vehicle Khishchnik-3930 [Digital resource] Access: <https://hishnikpro.ru/modelnyy-ryad/hishchnik-3930-1/> (Date 15.03.2024)]
2. Afanas'ev B.A., Belousov B.N., Gladov G.I. Proektirovanie polnoprivodnykh kolesnykh mashin T.1. Uchebnyk dlia vuzov. – M.: MGTU, 2008. – 496 s. [Afanas'ev B.A., Belousov B.N., Gladov G.I. Designing all-wheel drive vehicles Vol.1. Textbook for universities. – M.: MGTU, 2008. – p 496].

**Research adviser:** C.Sc. Gileta V.P.

**Language adviser:** C.Sc. Chesnokova R.A.

## **Influence of calcium hexaaluminate on physical and mechanical properties of alumina-zirconia based ceramics**

**Nomina Burkhinova**, Novosibirsk State Technical University, Novosibirsk, Russia, [nomina.burkhinova@mail.ru](mailto:nomina.burkhinova@mail.ru)

***Abstract:** This work considers the influence of the addition of calcium-hexaaluminate on microstructure, physical and mechanical properties of  $Al_2O_3$ -*

*ZrO<sub>2</sub>-CaO ceramics sintered at a temperature of 1520°C. As calcium hexaaluminate is sintered, both the grain size distributions of ZrO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> decrease. At the same time, the open porosity increases from 0.7% to 16% with increasing the content of CaAl<sub>12</sub>O<sub>19</sub>. The apparent density and hardness decrease by 5,5% and 14,9%, respectively. Fracture toughness increases from 5 to 5,7 MPa.*

**Keywords:** Alumina-zirconia, hexaaluminate calcium, denticity, hardness, fracture toughness

Alumina-zirconia based ceramics have many advantages, but similar to other ceramics, there are also some weaknesses, such as low resistance in brittle fracture. At the moment, there are a lot of ways to stop the forming and spreading of cracks in ceramic materials. In this particular research we used calcium hexaaluminate (CaAl<sub>12</sub>O<sub>19</sub>). The addition of hexaaluminate of alkaline earth metals is known to affect other properties of ceramics [1]. In the present work the effect of this additive on physical and mechanical properties of alumina-zirconia based ceramics, exactly density, porosity, hardness and fracture toughness are considered.

The starting materials used in this work were Al<sub>2</sub>O<sub>3</sub> produced by Almatix CT3000 SG with 99,7% purity, 3Y-ZrO<sub>2</sub> (PSZ-5.5YS, Stanford Materials) and CaO. The samples were formed using axial pressing at 100 MPa and sintered at 1520°C for 2 hours. As a result, four samples with different CA<sub>6</sub> content ( $C_{CaAl_{12}O_{19}} = 3, 6, 9$  and 12 wt.%) were obtained. The density was determined using the Archimedes method. The phase constitutes of Al<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub>-CaO ceramics were identified by X-ray diffraction. The microstructure of composites was observed by scanning electron microscope. The hardness and fracture toughness were measured using the indentation method with the 10 kg loads. The stress intensity factor ( $K_{Ic}$ ) was calculated according to the Niihara equation, taking into account the Young's modulus.

The XRD and SEM analysis indicated the formation of CaAl<sub>12</sub>O<sub>19</sub>. Microstructure of Al<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub>-CaO ceramics with equiaxed grains of aluminum oxide, spherical grains of zirconium dioxide, plated-like grains of CaAl<sub>12</sub>O<sub>19</sub> was obtained. Moreover, both the Al<sub>2</sub>O<sub>3</sub> and ZrO<sub>2</sub> average grain size decrease from 1 to 0,94 μm and from 0,43 to 0,38 μm, respectively, with increasing the content of calcium hexaaluminate.

The density of ceramics decreases with an increase in the content of calcium hexaaluminate. Porosity of the material increases with decreasing

density. The formation of pores can occur during the synthesis of  $\text{CaAl}_2\text{O}_9$  in the process of sintering [2].

Fig. 1 shows the hardness ( $\text{HV}_{10}$ ) and fracture toughness ( $K_{1c}$ ) of  $\text{Al}_2\text{O}_3$ - $\text{ZrO}_2$ -  $\text{CaAl}_2\text{O}_9$  ceramics with different content of  $\text{CaAl}_2\text{O}_9$ .

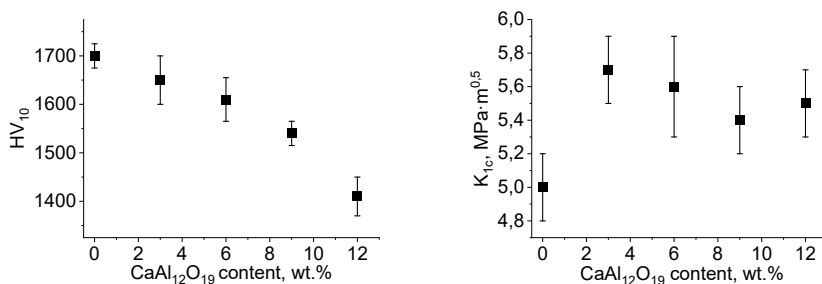


Figure 1 – The hardness and fracture toughness of ceramic composite

The hardness decreases from 1700 to 1410  $\text{HV}_{10}$  with increasing of calcium hexaaluminate content due to raise of porosity.  $K_{1c}$  (stress intensity factor) increase from 5 to 5,62 MPa. Platelet-like structure of  $\text{CaAl}_2\text{O}_9$  improve fracture toughness by crack deflection and crack branching mechanism.

The beneficent effect of calcium hexaaluminate on the fracture toughness of alumina-zirconia ceramics has been shown. The optimal values were obtained with calcium hexaaliminate content of 3 wt.%: the relative density is 96,6%, the open porosity is 0,7%. The maximum values of the hardness and fracture toughness are 1660  $\text{HV}_{10}$  and 5,62 MPa, respectively.

The research was conducted at core facility “Structure, mechanical and physical properties of materials”

## References

1. Liu X.Y. Fabrication and Properties of  $\text{CaAl}_2\text{O}_9$ - $\text{Al}_2\text{O}_3$  Composite Ceramics // Key Engineering Materials. – Trans Tech Publications Ltd, 2012. – vol. 512. –pp. 539-542.
2. Hossain S.S. Development of dense Sr-substituted  $\text{CaAl}_2\text{O}_9$  ( $\text{CA}_6$ ) ceramics synthesized by sol-gel combustion method //Journal of Asian Ceramic Societies. – 2021. – vol. 9. – No. 3. – pp. 1007-1014.

**Research adviser:** Assoc. Prof. Nina Yu. Cherkasova, Cand. Sc. (Eng.).

**Language adviser:** Assoc. Prof. Natalia P. Medvedeva, Cand.Sc. in Economics.

## **The Selection of Rational Technology for Composite Aerospace Products Manufacturing**

**Maxim Permikin**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[maksimpermikin@mail.ru](mailto:maksimpermikin@mail.ru)

**Maria Ivanova**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[ivanova777888@yandex.ru](mailto:ivanova777888@yandex.ru)

***Abstract:** The analysis of technologies and the equipment used in their implementation in the practice of composite aerospace products manufacturing will allow us to select the most rational method of processing products. This article analyses the most common equipment for composite products manufacturing.*

***Keywords:** composite, carbon, fiber, aerospace, technology, manufacturing, automated fiber placement, automated tape laying, 3D printing.*

In recent years, composite materials such as carbon, fiberglass, and Kevlar have emerged as fundamental components in multiple industries, with a pronounced impact on aerospace applications. The increasing utilization of these materials can be attributed to their exceptional strength properties and minimal weight characteristics, emphasizing their significance in advancing technological innovation and performance within the aerospace sector.

However, composite products face a significant challenge today due to their high manufacturing costs, making cost efficiency a crucial issue. This is primarily attributed to underdeveloped composite manufacturing technologies. Conventional technology involves the manual lay-up (molding), which consists of laying prepregs on a pre-made master model sequentially layer by layer and further polymerization in an autoclave.

A conventional technology has a number of serious disadvantages that affect production costs. To minimize these disadvantages the following measures should be taken:

1. Increase productivity and speed of manufacturing processes.
2. Eliminate the human factor, thereby increasing product quality.
3. Ensure savings in consumable raw materials – components (fiber and resin) that make up the composite material.

4. Ensure labor safety and minimize harmful production factors.

5. Organize flexible manufacturing – ensure the ability to manufacture products of any shape and dimensions without using of master models.

To achieve these goals, it's necessary to introduce automated manufacturing. There are several types of automated technologies – automated fiber placement (AFP) and automated tape laying (ATL), as well as continuous fiber reinforced polymer 3D printing (CFRP 3D printing).

AFP and ATL technologies are performed on a multi-axis CNC machine or a robotic manipulator. This equipment contains a «laying out» head, which ensures a mechanochemical reaction for joining the layers [1].

CFRP 3D printing is identical to the commonly used today FDM (fused deposition modeling) 3D printing; however the equipment used has design features that allow the use of special continuous fiber reinforced filaments [2].

Using AFP/ATL technologies, most goals can be achieved, with the exception of manufacturing flexibility, since a master model is still required. When using CFRP 3D printing technology, productivity remains low, but here we can implement production flexibility.

In addition, we should not forget about the possible machining of composites, which is often necessary after any fiber laying technology. Machining can be done either manually or using a CNC system.

The advantages and disadvantages of the technologies listed in this article are clearly presented in Table 1.

Table 1 – Advantages and disadvantages of the considered technologies

Measures	Conventional technology	Automated technologies		Innovative technology
	Hand lay-up (molding)	Automated fiber placement and tape laying (AFP / ATL)	Continuous fiber reinforced polymer 3D printing (CFRP 3D)	Combination of CFRP 3D printing, AFP / ATL and CNC machining
Increase in productivity	NO	YES	NO	YES
Eliminating the human factor and improving product quality	NO	YES	YES	YES
Ensuring raw material savings	NO	YES	YES	YES
Ensuring occupational safety and health	NO	YES	YES	YES

Organizing of flexible production (without using master models)	NO	NO	YES	YES
---	----	----	-----	-----

Table 1 also presents an innovative technology that combines automated fiber placement/tape laying (AFP/ATL), continuous fiber reinforced polymer 3D printing (CFRP 3D printing) and CNC machining technologies. This combination eliminates the disadvantages of each technology separately and ensures the achievement of all our goals.

This innovative technology will be implemented on one hybrid machine. The first few layers and complex infill will be printed using CFRP 3D printing technology. The vast majority of solid and mesh layers will be laid out using AFP/ATL technologies. The final stage is CNC machining. The process of laying composite layers is shown in Figure 1.

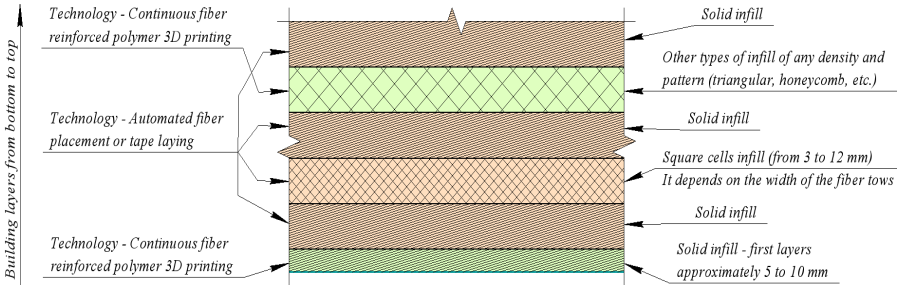


Figure 1 – An example of a laying scheme for composite layers

In conclusion, the most effective way to produce composite products in the aerospace industry is to use innovative combined technology that provides manufacturing flexibility, labor safety and material savings, high performance and product quality, thereby reducing production costs.

## References

1. Brasington A., Sacco C. [et al.]. Automated Fiber Placement: Review of history, current technologies, and future paths forward [Electronic resource] // Composites Part C: Open Access – Volume 6 (October, 2021) – Elsevier B.V. – Columbia, 2021. – URL: <https://doi.org/10.1016/j.jcomc.2021.100182> (accessed 12.10.2023).
2. Anbalagan A., Launchbury E.J. [et al.]. Investigation on CFRP 3D printing build parameters and their effect on topologically optimized complex models [Electronic resource] // Materials Today: Proceedings, 2023 – Elsevier B.V. –

Coventry, 2023. – URL: <https://doi.org/10.1016/j.matpr.2023.04.352> (accessed 13.10.2023).

**Research adviser:** Vladimir V. Ivancivsky, D.Sc. (Engineering).

**Language adviser:** Natalya P. Medvedeva, Ph.D. (Economics).

## **PHYSICAL ENGINEERING**

### **Laser cooling of ytterbium-171 ion in the field of three light waves**

**Denis Krysenko**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[denizkrysenko@yandex.ru](mailto:denizkrysenko@yandex.ru)

***Abstract:** The possibility of laser cooling of the ytterbium-171 ion in the light field of three frequency components without the use of magnetic fields was investigated. It has been shown that Doppler limit of laser cooling is reached at parameters corresponding two-level atom model. The considered method of laser cooling allows suppressing the shifts associated with the quadratic Zeeman effect.*

***Keywords:** laser cooling, polychromatic field,  $^{171}\text{Yb}^+$  ion.*

At present time, cold ions are used in optical clocks, which have a many fundamental applications. The achieved level of accuracy in optical frequency standards  $\Delta\nu/\nu < 10^{-18}$  creates new opportunities for development of modern fundamental researches. One of the most promising areas using cold atoms and ions is the development of modern optical frequency standards, for which the  $^{171}\text{Yb}^+$  ion is one of the main candidates [1]. Atomic interferometers on cold ions are used to test fundamental theories (e.g. Einstein's General Theory of Relativity) and measurements of physical constants (e.g. the gravitational constant).

The feature of laser cooling  $^{171}\text{Yb}^+$  of ytterbium ions consists in the fact that the optical transition  $^2S_{1/2} \rightarrow ^2P_{1/2}$  has two energy levels at the ground and excited states with angular moments  $F = 0$  and  $F = 1$ . The main complexity here is that the transition  $^2S_{1/2} \rightarrow ^2P_{1/2}$  used for laser cooling is not closed, it requires applying of a laser field with at least two frequency components and external magnetic field. In this case, the use of a relatively large magnetic field of 1-10 G is necessary to eliminate coherent population trapping (CPT) effect at the  $^2S_{1/2} (F=1)$  state for the cooling stage [2]. The basic problem: the



hysteresis effects during the switching off the magnetic field create certain difficulties in minimizing the residual magnetic field and keeping it constant in various cycles of cooling and clock operation.

Therefore, development of new methods of laser cooling of the  $^{171}\text{Yb}^+$  ion is a key step towards further implementation of precision methods for interrogating the ion in the trap.

In this work, a new method of laser cooling of  $^{171}\text{Yb}^+$  is proposed. The method does not include the use of a magnetic field and suggests the use of a polychromatic field of three light waves for Doppler laser cooling.

In the current work, numerical calculations and analytical expressions are performed. The optimal values of the parameters of the three waves are determined, and the optimal configuration of the light field is found to achieve the lowest temperature of laser cooling of  $^{171}\text{Yb}^+$ .

### References

1. Gao Kelin, National Science Review, 2020, v.7, 1799–1801.
2. Fisk P. T. H., Lawn M. A., Coles C., Applied Physics B: Lasers and Optics, 1993, v.57, 287-291.

**Research adviser:** Doctor of Sciences in Physical and Mathematical Sciences, O.N. Prudnikov.

**Language adviser:** N. A. Sapchenko, Cand. Sc. (Ped.).

### Modeling absorption infrared triplet of oxygen atom in the atmosphere of the exoplanet KELT-9b

**Maksim Golubovsky**<sup>1</sup>, Novosibirsk State Technical University, Novosibirsk, Russia, [maxym9121@gmail.com](mailto:maxym9121@gmail.com)

**Abstract:** *This paper provides the modeling results of absorption oxygen atom triplet with wavelength 777.4 nm in atmosphere of ultrahot Jupiter KELT-9b. There was used 3D magnetohydrodynamics model of atmosphere. This triplet was the first oxygen triplet in infrared range that was observed in atmosphere of exoplanets.*

**Key words:** *oxygen, hot Jupiter, non-local thermodynamic equilibrium, hydrodynamics*

The oxygen atom triplet with wavelength 777.4 nm is the first infrared (IR) oxygen triplet that was observed in atmosphere of exoplanet [1]. And it was found in atmosphere of KELT-9b. This triplet has several features that can make it very useful for future observation. But the absorption of this triplet was found only in one exoplanetary atmosphere yet. Later maybe there will be more observation data.

KELT-9b is the hottest ever observed exoplanet, its temperature is 3921 k. Also, this exoplanet is large and heavy: the radius is about 1.84 radii of Jupiter and the mass is close to 2.88 Jupiter mass. This exoplanet is slightly hard to simulate due to its features.

Observation absorption and simulation of it was provided in the [1]. It was made taking into account local thermodynamic equilibrium (LTE) and without it (NLTE). In exoplanetary astrophysics absorption is the fraction of star intensity in primary transit and outside of it. Primary transit is the center point of the planet's passage through the star's disk, and at this point the absorption is the greatest.

This work can be divided into three turns. The first turn is a creation of the exoplanet atmosphere using the model of atmosphere with the parameters of it and some free parameters of calculation. The second turn is a finding the abundance of lower level of oxygen triplet using kinetic model of oxygen. And last turn is finding the absorption using absorption model.

3D magnetohydrodynamics atmosphere model [2] was used in this work. It is a very complex model taking into account a large number of parameters, such as the abundance of hydrogen and helium in the atmosphere of the exoplanet, its temperature, a spectrum of a parent star, the presence of heavy elements, for example oxygen, magnesium, sodium and some other parameters. Abundance of all using in model elements equals the solar abundance by default. The resulted atmosphere is used in the kinetic model.

A kinetic model is the model that calculates the population of the lower level of triplet. The transition from it creates the absorption. This model takes into account such processes as photoionization, photoexcitation, recombination, a radiative decay and transitions via electron collisions. The photoexcitation is calculated with taking into account a trapping effect which is very important, because photoexcitation is the main pumping mechanism,

therefore proper value of it is the basis of correct model for this case. The result of this model is used in the last turn of the work: absorption calculation.

The absorption model is quite standard. It is used Voigt profile for calculation. This model also has free parameters but they are easy and obvious. The example of a parameter is the limit of velocity for absorption calculation. The spatial limits have to be also set. This model calculates the absorption in primary transit by default, but can be found for other phases of exoplanet movement.

The main results of this work are the two absorption profiles, the first for LTE and the second for NLTE cases. This was made, because such two profiles were provided in the [1]. In conclusion profiles calculated in this work, profiles from [1] and observation data are shown in Figure 1.

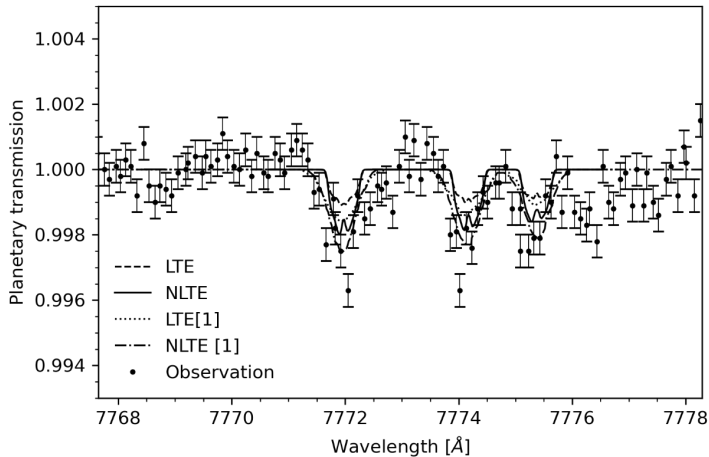


Figure 1 Absorption profiles

## References

1. Borsa F., Luca F., Tommi K. et al. High-resolution detection of neutral oxygen and non-LTE effects in the atmosphere of KELT-9b // *Nature Astronomy*. 2021. V. 6. No. 2. P. 226–231.
2. Shaikhislamov I.F., Khodachenko M.L., Lammer H. et al. 3D Aeronomy modelling of close-in exoplanets // *Monthly Notices of the Royal Astronomical Society*. 2018. V. 481. Iss. 4. P. 5315–5323.

**Research adviser:** I.F. Shaikhislamov, Doctor of Sciences in Physical and Mathematical Sciences

**Language adviser:** N.A. Sapchenko, Cand.Sc. (Ped.)

## **RADIO ENGINEERING AND ELECTRONICS**

### **Research of DMR signal demodulation using practical implementation technique**

**Egor Alushkin**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[radioengineer@ealushkin.ru](mailto:radioengineer@ealushkin.ru)

***Abstract:** This paper deals with the modelling of digital algorithm designed to demodulate DMR (Digital Mobile Radio) signals. Visual Studio Code environment, distributed free of charge, is used for modelling. Modelling is carried out in Python programming language in Jupiter Notebook format. The paper contains intermediate results of the master's thesis. The results of this work will provide an additional spectrum to be used for digital signals.*

***Keywords:** DMR, demodulation, 4FSK, frequency spectrum, signal, effective frequency bandwidth.*

Today there is a great demand for the use of radio frequency spectrum. More and more organizations are seeking to have their own dedicated frequency band. Like most natural resources, the radio frequency spectrum has its limitations. In order to meet the increasing demand and provide access to as many consumers as possible, it is necessary to reduce the effective frequency bandwidth of transmitted information. In order to optimize the use of electromagnetic frequencies, the ETSI TS 361-1 v2.1.1 standard TS 361-1 v2.1.1 "Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems" was created in 2013, which has very stringent requirements for the signal bandwidth to be 12.5 kHz and in some cases 6.25 kHz. [1, 2] Providing such a narrow frequency bandwidth, requires special methods of efficient digital modulation and coding.

In order to study the above telecommunication standard not only from a theoretical but also from a practical point of view on the information portal [www.sdrplay.com](http://www.sdrplay.com) was found a record of the spectrum of DMR-signal,

recorded using the program “SDRuno” in the format of IQ-wav file, which contains information about the in-phase (I) and quadrature (Q) components of the signal. The file was recorded from the ISS cross-band repeater on 11 September 2020.

At this stage of the research, it was possible to highlight the information encapsulated in the source file. This information is a frequency spectrum of the received signal, in which four carriers, peculiar to 4FSK manipulation, are clearly observed. In the future, this spectrum will serve as a basis for decoding the digital signal, that is, conversion into the form of audio messages and listening.

### References

1. Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems –Part 1: DMR Voice and Generic Services and Facilities, ETSI std. TS 102-361-1, V 2.5.1, 2017.

2. Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems –Part 2: DMR Voice and Generic Services and Facilities, ETSI std. TS 102-361-1, V 2.5.1, 2017.

**Research adviser:** S.V. Tyrykin, Candidate of Technical Sciences

**Language adviser:** N.P. Medvedeva, Candidate of Economic Sciences

## THERMAL AND ELECTRIC ENERGY PRODUCTION

### **Ignition of blended fuel consisting of high-ash coal and sawdust.**

**Sergey Vinogradov**, Novosibirsk State Technical University, Novosibirsk,

Russian, [serj.vin@yandex.ru](mailto:serj.vin@yandex.ru)

**Anton Pochtar**, Novosibirsk State Technical University, Novosibirsk, Russian,

[antonpochtar01@mail.ru](mailto:antonpochtar01@mail.ru)

***Abstract:** This paper presents statistical data on the use of coal energy carrier and results on combustion of blended fuel obtained by mixing pine sawdust and low-reactive coal. A comparative analysis of the experimental results is carried out.*

***Keywords:** blended fuel, oil-free ignition, high-ash coal, sawdust.*

The question of application of high-ash coals in the world power engineering is more and more frequent. At the moment the share of coal

energy carrier in the world power engineering is about 30%, this value demonstrates the importance of coal in generation of electric and thermal energy all over the world.

Nowadays at TPPs fuel oil is not only a reserve fuel, but also a stoking fuel, due to which the coal flame in the boiler is stoked and lit. The use of fuel oil as a starter and reserve fuel at the plant has disadvantages in the form of emissions of toxic combustion products, high-cost relative to coal energy carrier and a number of operational problems [1].

This paper considers the possibility of using the oil-free ignition system at TPPs, which use high-ash coals as the main fuel, in the form of a tool for stoking and flame illumination of a pulverized coal-fired boiler unit.

For the experimental part, a blended powder fuel consisting of coal and vegetable raw materials (waste from woodworking enterprises) was created.

Experimental studies were carried out on a laboratory stand, equipped with a system of oil-free ignition (OFI), which includes a burner unit (BU) and an electro-ionization ignition device (EID), the system was described in detail in previous works [1]. The aim of the study is to expand the possibilities of ignition of coal energy carriers using SBR, as well as the practical application of this technology.

The investigated fuel consists of a mechanical mixture of Ekibastuz coal of KSN brand, sawdust and wood flour, the composition of the investigated mixtures is presented in Table No. 1

**Table 1 - Compositions of used fuels**

№	Mass ratio	
	Coal, %	Wood sawdust, %
1	70	30
2	85	15
3	90	10
4	100	0

Fuel was prepared using a laboratory ball and a drum mill. Such fuel will allow to expand the possibilities of SBR implementation at the stations with high-ash coal, where the yield of volatile elements is less than 25-30%.

During the experimental part, the fuel was fed tangentially by a screw dust feeder into the combustion unit for better mixing with the transport air and formation of a vortex plume in the internal volume of the combustion unit. During the experiment, fuel flow rates as well as air flow ones, and temperatures at characteristic points of the BU were recorded.

To create a starting point, an experiment with clean coal was conducted, it showed that the capabilities of SBR for its ignition are not enough, while due to the low content of volatile substances, to start the autothermal process the released heat is not enough.

In subsequent experiments, blended fuel was used to increase the volatile content. With a coal/wood ratio of 70/30, the autothermal process was started with a temperature in the core of the plume of more than 1100 degrees Celsius.

When the proportion of wood in the mixture was reduced to 15%, stable ignition was achieved and the temperature in the core of the flame reached 900-1000 degrees Celsius.

At further lowering of a share of wood in a composition up to 10% burning of a mix occurred with temperatures at the end of experiment at the level more than 1000 degrees, but at such a content of wood in a mix the shift of a graph of temperatures to the right that demonstrates a boundary composition of a mix which still allows to initiate burning steadily, but this process is delayed in time is noticeable.

The introduction of a highly reactive component in the fuel composition in the form of wood dust made it possible to obtain the necessary heat power for the beginning of volatiles release from the coal and initiation of the coke part.

The conducted firing experiments allow us to conclude that ignition of Ekibastuz coal with SBR is possible with the help of dual-fuel systems, the blended fuel achieves heating of BU with subsequent combustion of clean fuel.

## **References**

1. Pochtar, A.S.; Vinogradov, S.V.; Kuchanov, S.N. Oil-free ignition of the pulverized coal boiler units (in Russian) // Science. Technologies. Innovations: XVI All-Russian Scientific Conference of Young Scientists - 2022. - C. 219 - 220.

2. Patent 2410603, MPK F23Q5/00, F23Q13/00 Russian Federation. Device for plasma ignition of pulverized coal fuel / Y. I. Naumov - stated. 17.11.2009; published 27.01.2011.

3. Patent 2704178, MPK F23C99/00, F23Q5/00 Russian Federation. Device for fuel flaring / Yu. I. Naumov, P.B. Sterligov - avv. 21.02.2019; published 24.10.2019

**Research adviser:** Boyko E.E., Cand. T.Sc.

**Language adviser:** Nikroshkina S.V., PhD

## **Overview of combustion technology, moderate or intensive low-oxygen dilution**

**Igor Muravev**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[igormuravev228@gmail.com](mailto:igormuravev228@gmail.com).

***Abstract:** The paper presents the data obtained as a result of various researchers on the topic of MILD Combustion. This technology can significantly reduce harmful emissions from the combustion of solid fuels.*

***Keywords:** MILD, coal, biomass.*

### **The object and method of the study**

In this paper, the combustion of fuels such as coal and biomass is considered using the MILD method. This method implies the following principles:

a) Burning air is preheated to a temperature above 1000 C°, and in some cases up to 1300 C°.

b) The temperature at the outlet of the furnace should be only slightly higher by 50 - 100 C°, than the temperature of the combustion air burning.

c) The fuel injectors must be positioned at an optimal radial distance from the combustion air flow. Burning's fuel injectors must be positioned at an optimal radial distance from the combustion air flow. When injecting fuel into the hot recirculation zone, combustion products with a low oxygen concentration, usually 2-5% which leads to a decrease in NO<sub>x</sub>.

d) The fuel jets and the air flow for burning fuel must carry away a large amount of combustion products before they are mixed.

i) Burning should occur throughout the furnace, and according to observations, the flame is not visible. The temperature fields in the furnace are relatively uniform, only small differences should appear in the immediate vicinity of the nozzle. Exactly the same uniformity is observed with the oxygen field.

### **Coal burning**

In the study of coal fuel combustion, experimental data are given to the characteristics of the combustion of Ningdong pulverized coal. The analysis



of the results showed that with a decrease in oxygen content from 8.75% to 2.86%, the peak combustion temperature also decreased from 1426 K to 1336 K. The area of the cold area in the upper part of the burner also decreased. The data on the conducted experiments are shown in Table 1.

Experiment	CH <sub>4</sub> l/min	O <sub>2</sub> l/min	CO <sub>2</sub> l/min	O <sub>2</sub> % For burning coal	Particle size microns
1	3	7	25	2.86	0-180
2	3	8	27	5.26	0-180
3	3	9.5	26.5	8.75	0-180

*Table 1 – Conditions of experiments with Ningdong coal [1]*

The chemical and physical composition of soot has also changed. In the process of soot growth, surface growth and oxidation coexisted and competed with each other.

During the growth of soot, the average particle size, mass concentration and content of aromatic compounds in the soot first increase and then decrease as the oxidation reaction proceeds.

The authors of the study [2] on the combustion of a joint biomass mixture (a mixture of 50% (wt.) poplar sawdust with 50% (wt.) coal) note that the concentration of O<sub>2</sub> in the exhaust gases is at the level of approximately 7.00%. This oxygen content indicates that the combustion of a mixture of sawdust and bituminous coal is controlled in basically the same way under combustion conditions 1,2,3 (Table 2). With conventional combustion, the concentration of NO is 127 ppm. When combustion switches to MILD mode, NO emissions are sharply reduced by 45.5% (from 127 ppm to 69 ppm), which suggests that MILD combustion can effectively suppress NO emissions compared to conventional combustion by co-burning sawdust and bituminous coal fuel mixture. The reduction of NO emissions is about 30%-50%, or even higher [2]. The CO<sub>2</sub> concentration for the three test conditions is shown in table 2.

Conditions	CO <sub>2</sub> % (col.)	CO <sub>2</sub> % (ism.)	Error rate %
1	12.47	13.25	6.3
2	12.56	13.17	4.9
3	12.37	13.21	6.8

*Table 2 - CO<sub>2</sub> concentration for three test conditions*

## Results

When conducting experiments of this level, the following conclusions can be drawn [1,2]. During the growth of soot, the average particle size, mass concentration and content of aromatic compounds in the soot first increased and then decreased as the oxidation reaction proceeded.

And it can also be said that the high degree of burnout during the joint combustion of poplar sawdust and a mixture of bituminous coal proves that the combustion of a mixture of biomass can still demonstrate satisfactory combustion efficiency under MILD combustion conditions. And this method of burning a mixture of coal and biomass reduces NO emissions by 30%-50%.

## References

1. Liu C. Et al. Experimental studies on soot in MILD oxy-coal combustion flame: Sampling, microscopic characteristics, chemical compositions and formation mechanism //Combustion and Flame. – 2022. – T. 241. – C. 112094.
2. Hu F. et al. MILD combustion of co-firing biomass and pulverized coal fuel blend for heterogeneous fuel NO and PM<sub>2.5</sub> emissions reduction //Fuel Processing Technology. – 2022. – T. 230. – C. 107222

**Research adviser:** O. V. Borush, PhD in Engineering.

**Language adviser:** S. V. Nikroshkina, Cand.Sc. (Phil.).

## Scheme for utilization of flue gases from petroleum coke calcination plant

**Andrey Dorofeev**, Novosibirsk State Technical University, Novosibirsk, Russia, [dorofeev.2019@stud.nstu.ru](mailto:dorofeev.2019@stud.nstu.ru)

**Abstract:** *The paper considers the application areas of calcined petroleum coke, as well as the method of flue gas utilization after its production. The scheme of*

*operation of such a plant is given. The experience of using such solutions in the world is presented.*

**Keywords:** *petroleum coke, rotating drum, calcination, flue gas utilization*

The use of petroleum coke is widely developed in modern industry. Low content of metallic impurities and heteroelements (oxygen, sulfur, nitrogen), high activity, as well as the ability to increase electrical conductivity by several orders of magnitude ( $10^8$  times) due to changes in structure make petroleum coke an indispensable material used in different industries [1].

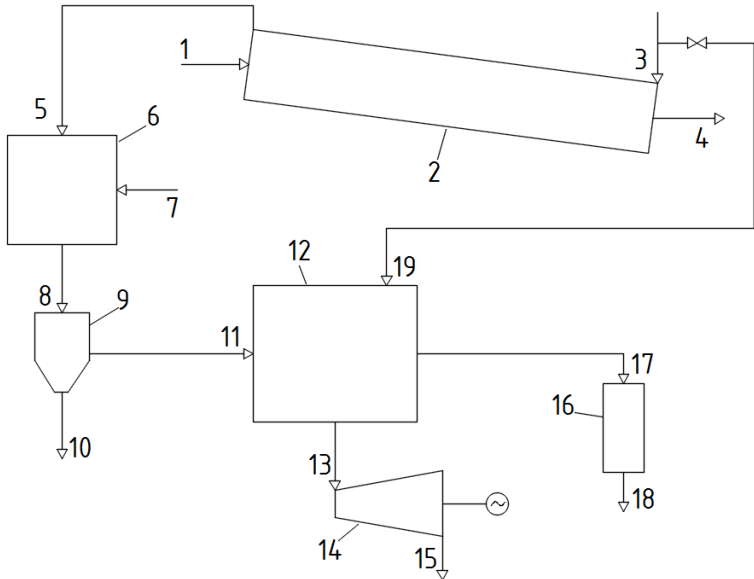
To transform the parameters of petroleum coke, calcination is used, in particular in a rotary drum furnace, which looks like a cylinder that is horizontally inclined to the ground, which allows to move the raw material naturally.

Calcination takes place during combustion of natural gas, it allows to clean the original raw material from unnecessary impurities, volatile components and coke dust, the final product is calcined coke, which is composed of 97-98% of carbon and residual nitrogen, sulfur and hydrogen [2].

The flue gases from this furnace are emitted into the atmosphere, even though their temperature may reach  $900^{\circ}\text{C}$ , and they may also contain mechanical and chemical underburning, represented by coke dust and  $\text{CO}$ , respectively.

One of the optimal solutions to this problem is a flue gas utilization line, which will allow converting thermal energy into electrical energy and obtaining an additional product - electricity.

The proposed line is presented schematically in Fig. 1, the cycle occurs in the following way: the dusty stream after the calcining furnace moves to the afterburning chamber, where the air necessary for afterburning is supplied, after the stream passes to the precipitation chamber, where the largest dust particles are removed, after the stream enters the waste heat boiler, where it



*Fig. 1 - Scheme of flue gas utilization line after drum calcining furnace: 1 - crude petroleum coke; 2 - drum calcining furnace; 3 - fuel supply (natural gas); 4 - removal of calcined coke from the furnace; 5 - supply to the flue gas afterburning chamber; 6 - afterburning chamber; 7 - supply of heated air; 8 - flue gas supply to the precipitation chamber; 9 - precipitation chamber; 10 - removal of precipitated particles; 11 - flue gas supply to HRSG; 12 - HRSG; 13 - superheated steam supply to steam turbine head; 14 - turbine unit; 15 - exhaust steam removal to condenser; 16 - flue gas cleaning filter; 17 - flue gas supply to filter; 18 - flue gas removal to chimney; 19 - natural gas supply to HRSG.*

transfers its thermal energy to the water in the screen pipes, heated air is also supplied to the boiler, it is necessary for CO afterburning. After the utilization boiler the gases go to the filter for purification before emission into the atmosphere. Steam generated in the utilization boiler, after separation, goes to the turbine unit. The boiler is provided with a natural gas supply, which is necessary for its continuous operation, even if the drum furnace is stopped.

A similar system has already been developed and implemented in Kazakhstan in Pavlodar, at the plant "UPNK-PV" for calcination of petroleum coke. On the territory of this enterprise there are 2 drum calcining furnaces with the length of 65 m each, they allow to produce more than 200 tons of

calcined coke per year, the fuel that is burned in these furnaces is fuel oil. The temperature of flue gas at the outlet of these furnaces is about 940 ° C and all this heat energy is utilized in two waste heat boilers, steam generating capacity of each of which is 35 tons/hour, this steam is supplied to 4 steam power plants, with a total electrical capacity of 12 MW. The treatment facilities are a bag filter and a desulphurization column [3].

The described and similar schemes allow increasing the efficiency of petroleum coke calcination plants due to the use of the whole range of available energy resources, in addition, due to the installation of modern gas cleaning systems, the environmental friendliness of production is increased. Electricity generation, which can be realized due to the proposed scheme, allows supplying it to external consumers and increasing the plant's own autonomy.

### References

1. Siuniaev Z.I. Proizvodstvo, oblagorazhivanie i primeneniia neftianogo koksa [Production, refining and applications of petroleum coke] - M.: Khimiia [Chemistry], Russia, 1973. - 296 s.

2. Iukhno D.S., Ermak A.A., Siubareva E.V. Izuchenie svoystv prokalennogo neftianogo koksa, poluchennogo iz distillatnogo i ostatochnogo syr'ia [Study of properties of calcined petroleum coke obtained from distillate and residual feedstock] // Vestnik Polotskogo gosudarstvennogo universiteta [Bulletin of Polotsk State University], Russia - 2022. - №10. - C. 110-114.

3. Description of the technological process [Electronic resource] // UPNK URL: <https://www.upnk.kz/ru/production/opisanietechprocessa> (date of reference: 02.11.2023).

**Research adviser:** O.K. Grigoreva, Candidate of technical sciences, associate professor

**Language adviser:** S.V. Nikroshkina, Candidate of sciences in Philology.

### Oil-free ignition of pulverized coal-fired boiler units

**Anton Pochtar**, Novosibirsk State Technical University, Novosibirsk, Russia,  
[antonpochtar01@mail.ru](mailto:antonpochtar01@mail.ru)

**Abstract:** *The paper presents statistical data on the use of coal in the countries of the Asia-Pacific region, enumerates the disadvantages of usage fuel oil as a stoking*

*fuel at power facilities, proposes several options for solving the environmental problem of reducing harmful emissions into the atmosphere when burning fuel oil.*

**Keywords:** *oil-free ignition system, plasma, stoking, illumination, coal ignition.*

Coal-fired generation of heat and electricity has a significant share in the global energy sector. At the moment, the share of coal energy carrier in the countries of the Asia-Pacific region is about 40% of the total industrial energy production. Coal production capacity at the beginning of 2023 was about 7.4 mln tons. The advantage of coal as an energy carrier is that it is cheaper than many other fuels, especially in the regions where it is mined. Directly for application of coal energy carrier at power plants, it is prepared by drying and grinding method on auxiliary boiler equipment. When pulverized coal is used at the plant as the main fuel, there is a need for ignition and flame lighting in pulverized coal boiler unit using highly reactive fuel oil. The use of this energy carrier produces toxic combustion products, namely sulfur oxides ( $\text{SO}_x$ ), benzpyrene ( $\text{C}_{20}\text{H}_{12}$ ) and vanadium (V) compounds [1], [2].

Every year all over the world regulations on emissions of combustion products are becoming stricter, thus increasing the cost of usage fuel oil. In addition, fuel oil has a high-cost relative to coal fuel and creates operational problems. Taking into account the aforementioned disadvantages of fuel oil, usage it can be conclude that nowadays it is very important to study technologies that allow to avoid fuel oil consumption.

In this case, the oil-free ignition system can completely replace the fuel oil at the moment of ignition and flame lighting of a pulverized coal-fired boiler unit.

This paper presents the results of research on ignition of various coals with different degrees of metamorphism using the SOFI system. The essence of the technology is the thermochemical initiation of combustion of the fuel-air mixture under conditions of air deficiency, due to the release of volatile elements contained in coal [2]. SOFI is a complex combining directly a cyclone burner with an axial electric muffle (Figure 1) and an electro-ionization ignition device (EID) (Figure 2) [3], [4].

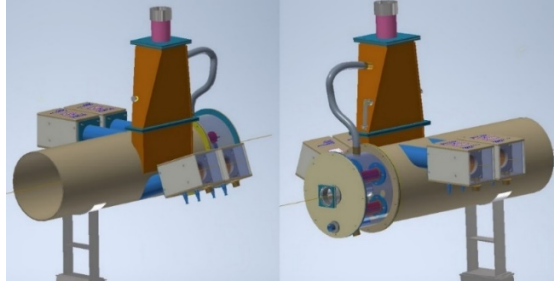
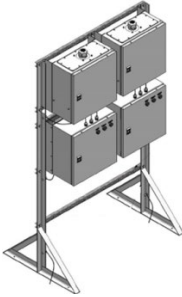
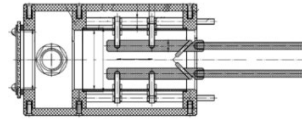


Fig.1 Types of 3D - model of the investigated burner device.



Power supply



Electrode block

Fig. 2 Electro-ionization ignition device.

As the results of SOFI performance, the authors present the material on ignition of lignite produced at the deposit located in Serbia, lignite of B2 grade from Borodino mine and D grade hard coal from Kuznetsk coal basin. The aim of the study is to determine the possibility of ignition of the coal fuel involved in the experiments, as well as to find the ratio of fuel to air flow rate for successful start of the autothermal combustion process in the burner device.

Before the experiments, the following factors of successful ignition triggering were adopted:

1. Rapid initiation of coal fuel ignition in the internal volume of the burner device.
2. High rate of temperature rise in the internal volume of the burner and the temperature of the flue gases.

3. Absence of dust inside the burner during the experiment (no underburning).

According to the results of the experiments, in which all factors of successful ignition start-up were fulfilled and autothermal process was achieved, it was observed that autothermics is characterized by high temperature of the burner barrel (550-650°C) [2].

### References

1. Pochtar A.S., Borush O.V. Oil-free ignition of pulverized coal-fired boiler units // Days of Science NSTU-2023: Proceedings of the Scientific Student Conference - 2023. - C. 100 - 103.

2. Plasmatoms: design, characteristics, calculation / A.S. Koroteev, V.M. Mironov, Y.S. Svirchuk. - Moscow: Mashinostroenie, 1993. - 296 c. ISBN 5-217-01342-7

3. Patent 2410603, MPK F23Q5/00, F23Q13/00 Russian Federation. Device for plasma ignition of pulverized coal fuel / Y. I. Naumov - stated. 17.11.2009; published 27.01.2011.

4. Patent 2704178, MPK F23C99/00, F23Q5/00 Russian Federation. Device for fuel flaring / Yu. I. Naumov, P.B. Sterligov - avv. 21.02.2019; published 24.10.2019

**Research adviser:** Borush O.V., Doctor of Technical Sciences, Associate Professor

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Candidate of sciences in Philology.

### Review of technologies for reducing nitrogen oxide emissions from thermal power plants. Low-emission burner systems.

Nikita Potkin, Novosibirsk State University, Novosibirsk, Russia,  
[potkin.2019@stud.nstu.ru](mailto:potkin.2019@stud.nstu.ru)

**Abstract:** *In this paper, various variants of low emission burner systems, their differences and similarities are discussed.*

**Keywords:** *nitrogen, burner, coal, oxygen, emissions.*

Modern low-NO<sub>x</sub> pulverized coal combustion systems, widely used today in power and industrial boilers, provide a sharp reduction of NO<sub>x</sub> emissions in a safe and efficient way. Retrofitting with low-NO<sub>x</sub> burners can reduce nitrogen oxide emissions by 40-70% at a capital cost of \$5-10 USD/kW [1].



In order to ensure low level of nitrogen oxide emissions such burners should: inhibit the mixing of oxygen-rich secondary air to the ignited aerosmash at the root of the flame; intensify heat and mass transfer between the aerosmash jet and high-temperature flue gases containing little oxygen, as well as between secondary air and flue gases; ensure efficient combustion of fuel at the minimum possible share of primary air; reduce the temperature peak in the combustion core without compromising the stability of ignition and efficiency of fuel burnout [2].

At the end of the 80s, EVT (Germany) and Combustion Engineering (USA) introduced direct-flow low-emission burners with separate nozzles of air mixture and secondary air, and their output velocities differ slightly from each other. The designers of the German company also installed tertiary air nozzles (10-15% of the theoretically required amount of air) above each burner for the 740 MW coal-fired unit. This modernization allowed to reduce emissions by about 20% [2].

Japanese specialists developed direct-flow burners with recirculation gas supply through independent nozzles, so-called SGR-burners and their modification PM-burners (Pollution Minimum). (Fig. 1) [2].

The principal difference between this burner and a conventional burner is the fuel supply by one nozzle - with increased concentration, and by the other - with decreased concentration [2].

For vortex burners, in turn, modification of the flaring process can be realized by changing the velocity mode, the proportion of primary and secondary air, as well as the twisting of separate streams of aerosmash and secondary air, etc. For the purpose of subsequent intensive mixing of air and burning coal dust, the secondary air from the outer channel can be supplied by direct flow. Such experiments were carried out on different boilers: P-57, where it was possible to reduce emissions from 0.97 to 0.55 g/m<sup>3</sup>, TPP-210A, burning Kuznetsk coal of LC grade - up to 30% reduction of emissions, as well as on the boiler BKZ-420-140-5, equipped with vortex burners with two channels of secondary air, see Fig. 2 [2].

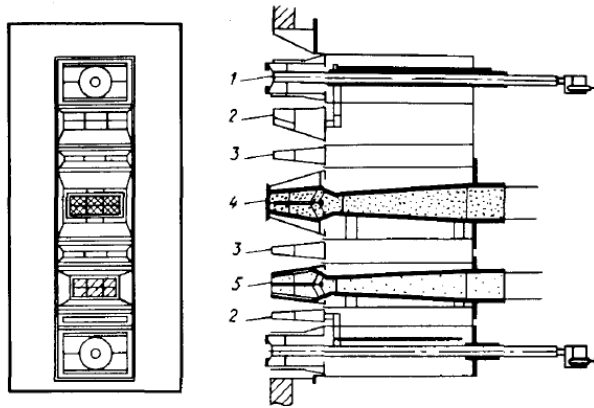


Fig. 1 Straight-flow burner of PM type (Japan) [2]

1 - fuel oil nozzle; 2 - secondary air; 3 - recirculation gases; 4 - aero-mixture with increased concentration of coal dust; 5 - aero-mixture with decreased concentration of dust.

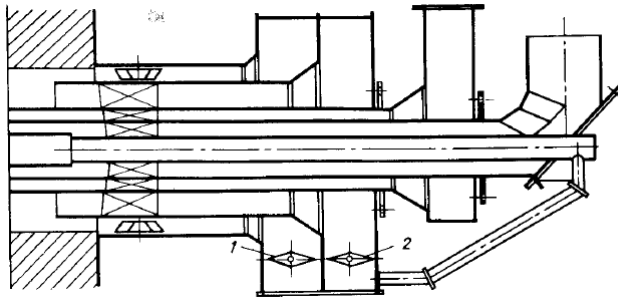


Fig. 2 Double swirl burner of boiler BKZ-420-140-5

1 - manually driven gate valve; 2 - intra-burner valve with CDU [2]

The same principle was used by the boiler-building firm Babcock-Wilcox (USA) when creating the so-called "double-register burners" (DRB) [2].

Typically, DRBs reduced nitrogen oxide emissions by 40-60% compared to the level of emissions without the use of special techniques [3].

One of the most advanced DRB burners is the third generation DRB-4Z burner. In this burner an additional air zone was added in contrast to the

previous generation, which acts as a buffer between the high-temperature fuel-rich flame core and secondary air streams. The flow field produced by the transition zone pulls gases from the outer portions of the flare inward toward the flare core.  $\text{NO}_x$  formed in the outer oxygen-rich portions of the plume is reduced to other nitrogen products in the process. Another advantage of the transition zone is the ability to change the stoichiometry of the primary zone.  $\text{NO}_x$  reductions of up to 80% of uncontrolled levels are possible with the DRB-4Z dual-register low-emission burner. This burner is well suited for use with OFA systems when the lowest  $\text{NO}_x$  emissions are required [3].

The layout of the DRB-4Z burner is shown in Fig. 3. The mechanical design combines the advanced aerodynamic properties and proven robustness of the DRB-XCL twin-register burner.

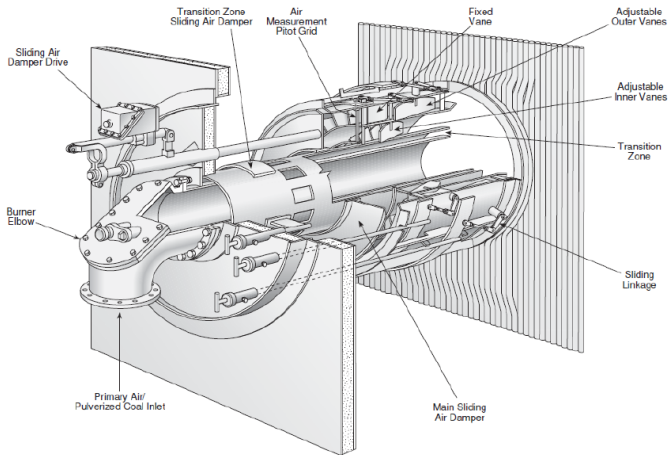


Fig. 3 Low-emission burner DRB-4Z for pulverized coal-fired boiler units [3]

## References

1. Kotler V.R., Batorshin V.A., A new stage in the fight against nitrogen oxide emissions at coal-fired thermal power plants // Energy management abroad. – 2017. – No.6. - pp. 29-32.
2. Kotler V.R. Nitrogen oxides in flue gases of boilers. – M.: Energoatomizdat, 1987. – 144 p.: ill. – (B-ka teploenergetika)

3. Stultz S.C., Kitto J.B. Steam: Its Generation and Use 41st Edition / The Babcock & Wilcox Company. – Akron, 2005. – 1040 p.

**Research adviser:** O.V. Borush, doctor of technical sciences, professor

**Language adviser:** Assoc. Prof. S.V. Nikroshkina, Candidate of sciences in Philology.

## **Technologies for ensuring environmental safety of coal POWER engineering**

**Anastasia Poleva**, Novosibirsk State Technical University, Novosibirsk, Russia,

[Nastena\\_7689@mail.ru](mailto:Nastena_7689@mail.ru)

**Abstract:** *The article describes the implementation of promising technologies and ideas, through the introduction of which thermal power plants will be able to reach a higher level of environmental friendliness, significantly reducing emissions and thermal pollution.*

**Keywords:** *environmental safety, flue gases, energy, harmful emissions, thermal power plant, environment.*

Coal-fired power generation occupies about 25% of the total world energy generation, and will not lose its relevance within 20 years [1]. In this regard, it is necessary to use new methods to reduce emissions from carbon energy.

Emission reduction methods are divided into two main types: technological and chemical (Scrubbers, emulsifiers, electrostatic precipitators, bag filters, combined cleaning systems (Fig. 1) [2,3]:

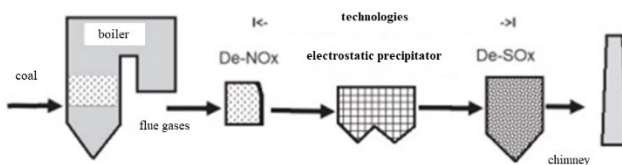


Figure 1 - Scheme for reduction of harmful emissions by gas flow

Ash collection. In recent years, improvements have been made in ESP and ash collector cleaning techniques, through the introduction of corona and

precipitation electrodes, which provide capture of dust of high resistance. Small-size drives replace the shaking system, allowing the use of partial converters to adjust the frequency and force of shaking. This significantly reduces secondary dust entrainment and eliminates the possibility of volley ash emissions [4,5].

Due to this, today electrostatic precipitators have a number of advantages, such as high efficiency coefficient of gas cleaning (99.95%), capture of particles as small as 0.01 micron, low hydraulic resistance, wide range of cleaning by volume of flue gases [4,5].

**Emissions of nitrogen oxides.** There are a number of measures to ensure nitrogen oxides capture at thermal power plants, the choice of which depends on the type of fuel, design features and boiler capacity. The technological measures include two-stage, three-stage and non-stoichiometric combustion, low-emission burners and their arrangement in the furnace chamber space, as well as combustion with moderate underburning of fuel. The most effective and popular technological measure is the arrangement of low-emission burners, providing staged combustion due to air distribution along the length of the flame [5]. Application of the above measures allows to reduce emissions of nitrogen oxides of boilers at solid bottom ash removal less than 300-350 mg/m<sup>3</sup>, and for liquid bottom ash removal less than 700-750 mg/m<sup>3</sup>.

**Sulphur oxide emissions.** At present, three main chemical methods of desulfurization by chemisorbents are used: dry, wet-dry and wet. The essence of the dry method is to use a sorbent such as limestone (CaCO<sub>3</sub>), quicklime (CaO) and slaked (Ca(OH)<sub>2</sub>) lime in the zone of high temperatures, which are about 1000°C. The efficiency of this method is 20-45% and is ineffective, due to the high consumption of sorbent and is used only on small and medium capacity boilers.

The method of wet-dry desulfurization is effective at 60-85% and is applied at combustion of coal with not high sulfur content [5]. They provide a long contact of flue gases with the slurry.

The methods and technologies under consideration are effective in ensuring environmental safety of coal-fired power plants, which occupy the main percentage in the generation of heat and electricity. Consequently,

further developments should be aimed at accelerating the development of technical equipment of this industry.

### References

1. Novak A.V. On the prospects of decarbonization and development of hydrogen energy in Russia // Proceedings of the XXVI St. Petersburg International Economic Forum "SPIEF'23". [Electronic resource]. - Access mode: <https://forumspb.com/news/news/aleksandr-novak-rasskazal-o-perspektivah-dekarbonizatsii-i-razvitii-vodorodnoj-energetiki-v-rossii/> (date of circulation 25.02.2024).

2. Gaak, V.K. Main directions of the thermal power engineering ecological efficiency increase (in Russian) / V.K. Gaak, A.Yu. Finichenko, A.V. Gaak // Izvestiya Transsiba / Omsk State Univ. of Railway Transport. - Omsk. - 2019. - № 4 (40). - C. 120 - 128.

**Research adviser:** P.A. Shinnikov, Doctor of Technical Sciences.

**Language adviser:** Nikroshkina S.V., Candidate of Philological Sciences.

### **Analysis of environmental efficiency change during replacement of flue gas desulfurization unit**

**Dariana Shpilevskaya**, Novosibirsk State Technical University, Novosibirsk, Russia, [daryanas01@mail.ru](mailto:daryanas01@mail.ru)

**Abstract:** *The article analyzes the effectiveness of implementing bag filters for the modernization of a thermal power plant (TPP) and reducing emissions*

**Keywords:** *bag filters, efficiency, assess, comparing, calculations.*

The assessment of the effectiveness of retrofitting boilers with bag filters can be conducted based on several criteria. It is important to consider that specific results depend on the type of boiler, operating conditions, and other factors.

Bag filters represent a more modern and efficient filtration technology compared to traditional methods. Their main advantage lies in their high degree of removal of solid particles from flue gases, which contributes to reducing atmospheric pollution and increasing the efficiency of heating systems. Thanks to their design, bag filters ensure stable and long-lasting equipment operation.

When comparing the effectiveness of bag filters with other types of ash capturing installations, several key aspects can be identified. Bag filters demonstrate a high capacity for capturing particles of various sizes, significantly enhancing the efficiency of gas stream purification. Additionally, they are characterized by a longer service life and lower maintenance costs compared to alternative methods.

To assess the effectiveness, a series of calculations will be conducted for the operation of the power unit based on the T-115-8.8 turbine in Seversk, receiving steam from various boiler groups. These boiler groups employ different ash cleaning systems. Following the comparative calculations, the efficiency of transitioning boilers to the use of bag filters will be determined.

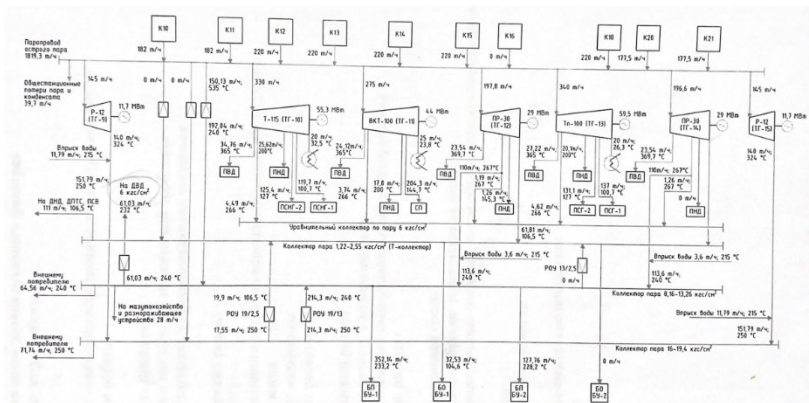


Fig.1 – Diagram of the Seversk station

## References

1. Yu.A. Krainova Bag filters // Bulletin of the magistracy. 2013. N94(19).
2. Stalinsky, D.V. New developments in the field of gas removal and gas purification systems from dust of the State Enterprise UkrNTC Energostal / D.V. Stalinsky, M.N. Shvets // Steel. - 2013. – No. 12. – pp. 76-81.

**Research adviser:** P.A. Shinnikov, Doctor of Technical Sciences, ProfessorAbstract

**Language adviser:** Nikroshkina S.V., Candidate of Philological Sciences

## **BUSINESS AND ECONOMICS**

### **Information Support for Analysis of Enterprise Activities**

#### **Abstract**

**Maksim Nikitin**, Siberian State Transport University, Novosibirsk, Russia, e-mail - [maksim\\_nik023@mail.ru](mailto:maksim_nik023@mail.ru)

***Abstract:** This paper addresses the critical role of information for analyzing enterprise activities. It focuses on its significance, existing classifications, and technological advancements. The study aims to identify the pivotal role of information in business analysis, discussing theoretical frameworks and classifications. The research intimately examines the diverse ways that information contributes to analyzing company operations, emphasizing its role in decision-making and strategy development.*

***Keywords:** information, data collection, big data, machine learning, information reliability, strategic planning, market analysis*

The object of the study covers various types and sources of information that are crucial for various departments of the enterprise, including strategic, accounting, marketing and technical information [4].

Various classifications of information are widely discussed nowadays in scientific literature. To justify the particular qualities of information it is essential to provide comprehensive understanding of the company's activities. Researchers and managers most commonly distinguish internal, external, public and non-public information (Table 1).

*Table 1 – Classification of information*

<b>Internal</b>	<b>External</b>	<b>Non-public</b>	<b>Public</b>
Information is created and used within the organization. Examples include internal reports, employees' records,	Information is obtained from outside the organization. Examples include market research reports, industry	Information is confidential and intended for a particular group of individuals. Examples include trade secrets, proprietary	Information is publicly available and accessible to anyone. Examples include public financial statements, press releases, and



and financial statements.	trends, and customer feedback.	technology, and confidential client data.	industry publications.
---------------------------	--------------------------------	---	------------------------

Strategic information serves as the basis for long-term planning and goal setting in organizations. It includes market trends, industry forecasts and competitor analysis, providing decision makers with invaluable information that will help the company achieve sustainable growth and competitive advantages [3].

Accounting information, on the other hand, provides a detailed view of the financial position of the company. Balance sheets, income statements and other accounting reports provide data that can help in budgeting, resource allocation and financial decision-making, ensuring financial responsibility and stability.

Marketing information is a cornerstone in the development of targeted strategies to improve market positioning, to retain existing customers and attract new ones. Through consumer behavior analysis, market segmentation, and competitive benchmarking, organizations can tailor their marketing efforts so that they effectively resonate with their target audience. In addition, technical information plays a key role in promoting innovation and improving operational efficiency. This data, from research and development information to manufacturing processes, simplifies operations, facilitates product development, and ensures compliance with industry standards and regulations.

The study emphasizes the importance of the reliability of information, highlights the factors influencing it, such as the reliability of the source of information, relevance, completeness and accuracy. To increase the reliability of the analysis results, methods for ensuring the accuracy of information, such as cross-validation, are being studied [1].

Reliable verification methods, including cross-references to multiple sources and triangulation of data, are necessary to reduce the risks associated with erroneous or biased information, thereby increasing the reliability of the analysis results (Fig.1).

In addition, the study examines the growing role of information systems in corporate analysis, emphasizing their capabilities in data collection, processing and analysis. Modern technologies such as artificial intelligence,

big data and machine learning are noted for their contribution to improving the efficiency, automation and accuracy of analysis. These technologies enable organizations to extract useful information from vast datasets, identify patterns, and predict future trends with unprecedented accuracy, allowing them to make large-scale data-driven decisions [2].

<b>Source credibility</b>	<ul style="list-style-type: none"> <li>• The reliability of information depends on the credibility and expense of the source.</li> </ul>
<b>Bias and objectives</b>	<ul style="list-style-type: none"> <li>• Information may be biased or subjective, affecting its reliability.</li> </ul>
<b>Timeliness</b>	<ul style="list-style-type: none"> <li>• Outdated information may not be reliable, as new data and developments can change the context.</li> </ul>
<b>Verification and corroboration</b>	<ul style="list-style-type: none"> <li>• Information that can be verified and corroborated by multiple sources is generally more reliable.</li> </ul>
<b>Methodology and research design</b>	<ul style="list-style-type: none"> <li>• The reliability of information is influenced by the rigor of the research methodology and design used to gather and analyze the data.</li> </ul>

*Figure 1 – Reliability of information*

In conclusion, the conducted analysis highlights the key role of information support in modern business, allowing organizations to make informed decisions and achieve their goals. It examines future developments in the field of information support, including the creation of new technologies and tools to improve data collection, analysis and reliability. The scope of application of the results obtained extends to enterprises in various industries, contributing to informed decision-making and strategic planning. As organizations continue to use the power of information, they are ready to confidently and flexibly navigate the complexities of the modern business landscape, while ensuring sustainable growth and competitive advantages.

### **References**

1. Balashova, O. D. Information support of enterprise management: achieving competitive advantages / O. D. Balashova, E. N. Nikolaeva // Bulletin of the PGUPS. - 2019. - No. 3. - pp. 16-26.

2. Belozerov, V. V. Information technologies and information systems in enterprise management / V. V. Belozerov. - M. : INFRA-M, 2017.

3. Zabludovsky, E. V. Information support of enterprise management / E. V. Zabludovskikh, D. V. Zabludovskikh. - M. : Ekon-Inform, 2018.

4. Zolotareva, G. V. Analysis of financial and economic activities of the enterprise / G. V. Zolotareva. - M. : Finance and Statistics, 2016.

**Research adviser:** Elena Surikova, Siberian State Transport University, Novosibirsk, Russia, *e-mail* – [surikovaea@sgups.stu.ru](mailto:surikovaea@sgups.stu.ru)

**Language adviser:** Elena Zharikova, Siberian State Transport University, Novosibirsk, Russia, *e-mail* – [jarikovalena@mail.ru](mailto:jarikovalena@mail.ru)

## THE IMPACT OF THE USE OF DIGITAL TECHNOLOGIES IN CONSTRUCTION TIME MANAGEMENT

Nikita Potekhin, MGSU, Moscow, Russia, [potexin-2001@mail.ru](mailto:potexin-2001@mail.ru)

**Abstract:** *The article examines the most promising technologies of the fourth industrial revolution, the ways of their application in construction time management and the possible effect of their application.*

**Keywords:** *Construction time management, Industry 4.0, digital technologies, Internet of things.*

Construction production is a complex sequence of interrelated processes, the end result of which is a completed and ready-to-use building or structure. One of the distinctive features of construction production is the significant duration of construction processes. High-quality organization of time and its effective use contributes to reducing the duration of construction processes, shorter time for obtaining final products and, as a result, increasing the final profit from the sale of products.

Time management technology fits perfectly into the construction industry, which is built on meeting various deadlines [1]. Time management is a set of methods for organizing time and increasing the efficiency of its use.

Modern time management includes the following processes:

- analysis of the required time;
- monitoring deadlines;
- setting and ranking deadlines;
- distribution of responsibilities and roles;

- Monitoring of key events;
- reflection.

The 21st century was the beginning of the fourth industrial revolution, which is called “Industry 4.0.” Industry 4.0 opens up a new approach to production based on the introduction of digital technologies into industry, automation of business processes, the development and application of artificial intelligence [2]. Digital technologies can find their application in construction time management. Let's look at two of the most relevant digital technologies in construction and consider the options for their application in construction time management, as well as the expected effect of their application.

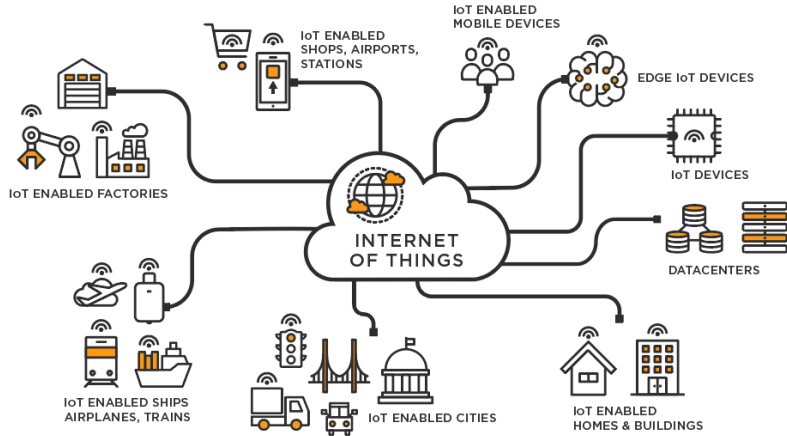
At the moment, the following digital technologies are the most relevant in construction:

1. Information Modeling Technology (TIM). TIM refers to the creation of a digital information model (CIM) of a building with a certain degree of geometric details, which contains a certain set of attribute data about each finite element of the building. Figure 1 shows an example of a complete digital information model of a building.



*Figure 1 – An example of a digital information model of a building.*

2. The Internet of Things and smart sensors. This technology involves connecting all machines, mechanisms, objects and even workers into a single network, which allows you to track all the necessary indicators in real time. The scheme of the Internet of Things is shown in Figure 2.



*Figure 2 – The scheme of the Internet of Things.*

Let's consider what application the considered technologies can find in construction time management.

The digital information model obtained with the help of information modeling technology helps in performing many tasks of construction time management. The model contains a lot of different data, for example, geometric parameters, weight parameters, cost and time parameters. High-quality DIM, produced in compliance with all requirements and norms, allows you to automatically obtain a plan for the execution of construction and installation works with minimal labor costs. The resulting DIM-linked plan is a 4D model of the facility, which makes it easier to monitor the progress of construction processes and accessible to all construction participants, as well as respond to emerging changes in a timely manner.

The Internet of Things and smart sensors allow you to combine all the elements of the construction process together and receive large amounts of information from them in real time, collecting them in one place. Using environmental sensors, various sensors installed in machines and mechanisms, smart watches etc., the time manager receives information about the state of the elements of the construction process and can predict emerging changes based on the information received, respond to them in a timely manner and make necessary management decisions in order to comply with the deadlines allowed for the project plan.

Using the achievements of the fourth Industrial Revolution in construction time management processes increases their efficiency and quality, and can also bring construction to a new level of efficiency in general.

#### References:

1. Nadezhda Storchai. Time management in construction //Educational portal “Directory”. — Date of the last update of the article: 11.10.2023. — URL [https://spravochnick.ru/arhitektura\\_i\\_stroitelstvo/taym-menedzhment\\_v\\_stroitelstve/](https://spravochnick.ru/arhitektura_i_stroitelstvo/taym-menedzhment_v_stroitelstve/) (date of reference: 02/01/2024).
2. The Fourth Industrial Revolution: digital production and the industrial Internet of Things / A. B. Syritsky, K. G. Potapov, M. I. Kiselyov, A. S. Komshin // Standards and Quality. – 2018. – No. 6. – pp. 64-68. – EDN UQDZDM.

**Research adviser:** I.P Pavlyuchko, Cand. Sc. (Philology), Assoc. Prof.

**Language adviser:** I.P. Pavlyuchko, Cand. Sc. (Philology), Assoc. Prof.

## GERMAN SESSION

### Herstellung, Mikrostruktur und mechanische Eigenschaften von Borkarbid-Chromdiborid Keramik

**Dmitry Dik**, Staatliche Technische Universität Nowosibirsk,  
Nowosibirsk, Russland, [dickdmit@yandex.ru](mailto:dickdmit@yandex.ru)

**Annotation:** *In der vorliegenden Arbeit wird die Mikrostruktur von Verbundkeramik  $B_4C-CrB_2$  im Bereich von  $CrB_2$  Zusatzstoffkonzentrationen von 5-30% betrachtet, die durch Reduktion von Chromoxid im Überschuss von Borkarbid unter Verwendung von nanofaserigem Kohlenstoff erhalten werden. Die Abhängigkeiten von Teilchengröße, Härte, Dichte, Elastizitätsmodul und Bruchfestigkeit von der  $CrB_2$ -Konzentration wurden ermittelt und unter dargestellt.*

**Schlüsselwörter:** *Keramik, Borkarbid, Chromdiborid, mechanische Eigenschaften.*

Borkarbid weist hohe Werte bei Härte, Festigkeit, chemischer Inertheit und Wärmebeständigkeit auf. Dies macht Borkarbidkeramik zu einem vielversprechenden Werkstoff für Anwendungen in Bereichen mit rauen Betriebsbedingungen [1]. Allerdings werden seine Produkte aufgrund der geringen Sinterfähigkeit durch komplexe und teure technologische Prozesse

der Verdichtung gewonnen. Und die geringe Bruchzähigkeit dieser Keramiken schränkt ihre Anwendung unter hohen Stoßbelastungen ein. Daher wird nach Sinteradditiven geforscht, die diese Probleme lösen und eine hohe Härte und geringe Dichte gewährleisten [2].

In dieser Arbeit wird Chromdiborid als ein solcher Zusatzstoff gewählt. Es unterscheidet sich von anderen Diboriden dadurch, dass es mit Borkarbid ein System mit der niedrigsten eutektischen Temperatur bildet. Dadurch ist es möglich, die Sinterparameter zu minimieren und kleine Mengen an Sinterhilfsmittel mit spürbaren Veränderungen der mechanischen Eigenschaften einzuführen.

Für die Herstellung der Reaktionsmischungen wurden Pulver aus Chromoxid und Borkarbid mit einer Größe von 1-2  $\mu\text{m}$  sowie nanofaseriger Kohlenstoff mit einer spezifischen Oberfläche von 150  $\text{m}^2/\text{g}$  verwendet. Die Keramik  $\text{B}_4\text{C-CrB}_2$  wurde durch Carbido-Bor-Reduktion von Chromoxid in Gegenwart von nanofaserigem Kohlenstoff hergestellt.

In dieser Arbeit wurden Keramiken mit einer Zusammensetzung von 5-30 mol%  $\text{CrB}_2$  untersucht. Die Feinteile für die Keramikherstellung wurden auf einer kompakten Labor-Heißpresse bei einer maximalen Presskraft von 17,5 MPa und einer maximalen Temperatur von 2000  $^\circ\text{C}$  gepresst, wobei die maximalen Pressparameter 10 Minuten lang in Argon-Atmosphäre gehalten wurden.

Abbildung 1 zeigt elektronische Fotos der Proben, anhand derer die Mikrostrukturparameter bewertet wurden. Diese Daten sind in Tabelle 1 aufgeführt:  $S_{80}$  ist die Obergrenze der Fläche der Partikelmasse (80 % der Partikel sind kleiner als diese Fläche); der prozentuale Anteil der Anzahl der Partikel, die größer als diese Fläche sind;  $S_{65}/S_{35}$  (Verhältnis der Obergrenze der Fläche der 65% kleineren Partikel zur Obergrenze der Fläche der 35% kleineren Partikel) ist der Steigungskoeffizient der kumulativen Geraden; die scheinbare Porosität ist der prozentuale Anteil der Fläche des Elektronenfotos, der von Poren eingenommen wird.

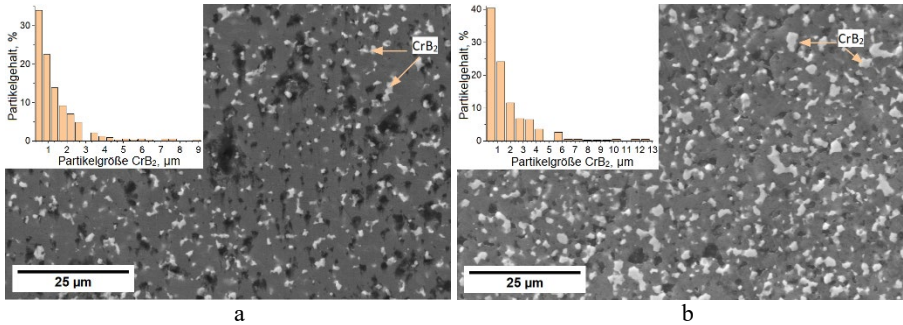


Abbildung 1. Mikrostruktur und Partikelverteilung von  $B_4C-CrB_2$ -Keramiken  
a - 10 mol%  $CrB_2$ ; b - 20 mol%  $CrB_2$

Tabelle 1-Keramische Gefügeparameter  $B_4C-CrB_2$ -Keramiken

	10 mol% $CrB_2$	Artikel [1]	20 mol% $CrB_2$	Artikel [2]	30 mol% $CrB_2$
$S_{80}$ , $\mu m$	1,45	2,05	1,9	2,4	5,05
% der Partikel > $S_{80}$	1	2,5	3,5	6,5	20,5
$S_{65}/S_{35}$	2	2,18	2,1	1,63	1,91
Scheinbare Porosität, %	13	-	15	-	17

Die Dichte der Proben wurde durch hydrostatisches Wiegen gemessen. Die Abhängigkeiten der Dichte von der  $CrB_2$ -Konzentration wurden ermittelt, sie sind in Abbildung 2(a) dargestellt. Alle Werte sind größer als 90%, was darauf hindeutet, dass die Bedingungen des Heißpressens ausreichen, um eine Sinterung zu gewährleisten. Die Mikrohärtigkeit der Proben wurde durch Nanoindentation bestimmt und ist in Abbildung 2(b) dargestellt. Die Härteergebnisse von Zusammensetzungen mit bis zu 10 mol-%  $CrB_2$  sind größer oder gleich denen von Wolframkarbid.



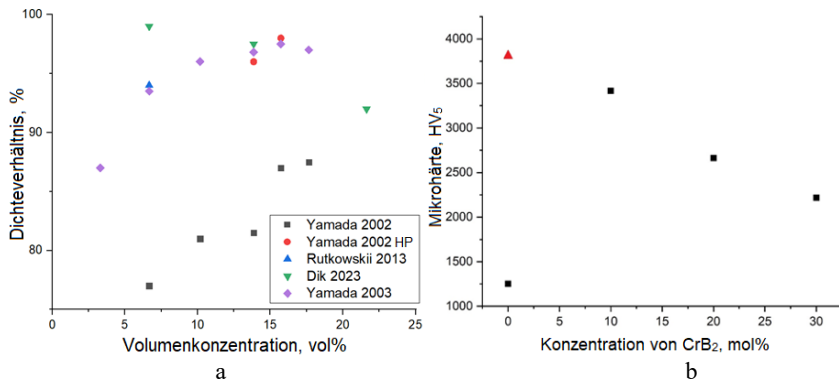


Abbildung 2. Abhängigkeiten der Konzentration in Keramik  $B_4C-CrB_2$ : a - Dichte im Vergleich zu anderen Formgebungsverfahren; b - Mikrohärtigkeit

Mikrostruktur und Eigenschaften (Dichte, Mikrohärtigkeit, Elastizitätsmodul, Bruchfestigkeit) wurden für die erhaltenen keramischen Werkstoffe Borcarbid-Chromdiborid untersucht. Die erhaltenen Keramiken weisen im Vergleich zu den analogen Werkstoffen bessere mikrostrukturelle Parameter und hohe Werte für Dichte und Härte auf, was auf die Vollständigkeit des Sinterprozesses durch den Zusatz von Chromdiborid schließen lässt.

#### Referenzen:

1. Wang S., Xing P., Gao S. et al. Effect of in-situ formed  $CrB_2$  on pressureless sintering of  $B_4C$ //Ceram. Int., 2018. V. 44, №.16. P. 20367-74.
2. Yamada S., Hirao K., Yamauchi Y. and Kanzaki S. Sintering behavior of  $B_4C-CrB_2$  ceramics // J. Mater. Sci. Lett. 2002. V. 21. P. 1445-7.

**Wissenschaftlicher Mitarbeiter:** N. Yu. Cherkasova, Kandidat der technischen Wissenschaften.

**Sprachberaterin:** L. F. Luchikhina, Cheflektorin.

### Anpassung von Webschnittstellen auf der Grundlage einer Analyse des Nutzerverhaltens

Natalia Potekhina, Novosibirsker Staatliche Technische Universität, Novosibirsk, Russland,

[natali-potekhina@mail.ru](mailto:natali-potekhina@mail.ru)

**Zusammenfassung:** Der Beitrag beschreibt die Verwendung von Daten zum Nutzerverhalten zur Erstellung personalisierter Schnittstellen und

*Anpassungstechniken, einschließlich dynamischer Schnittstellenmodifikation, Anwendung von maschinellem Lernen und künstlicher Intelligenz. Der Schwerpunkt liegt auf der Bedeutung der Sammlung und Analyse von Daten zum Nutzerverhalten, um die Anpassung von Webschnittstellen zu verbessern und die Nutzererfahrung zu optimieren.*

**Schlüsselwörter:** *Anpassungsfähigkeit, Modelle des Nutzerverhaltens, Personalisierung, dynamische Schnittstellenänderung, Datenerfassung und -analyse, maschinelles Lernen, künstliche Intelligenz.*

In der heutigen Welt spielen Webschnittstellen eine Schlüsselrolle für das Nutzererlebnis. Die Vielfalt der Nutzer und ihre individuellen Vorlieben stellen die Entwickler jedoch vor eine Herausforderung: Wie kann man sicherstellen, dass Webschnittstellen an unterschiedliche Verhaltensweisen angepasst werden können?

Benutzerverhaltensmodelle spielen in der Webentwicklung eine Schlüsselrolle bei der Anpassung von Webschnittstellen. Sie sind strukturierte Beschreibungen typischer Benutzeraktionen und -präferenzen bei der Nutzung einer Schnittstelle. Diese Modelle können aus Daten über Benutzeraktivitäten wie Klicks, Scrollen, Zeitintervalle zwischen Aktionen und anderen Parametern erstellt werden. Das Verständnis dieser Modelle hilft den Entwicklern, die Benutzererfahrung zu verbessern und die Effizienz der Interaktion mit der Schnittstelle zu steigern. Die Analyse des Nutzerverhaltens in der Online-Umgebung kann Trends, Vorlieben und Bedürfnisse der Nutzer aufzeigen, was wiederum dazu beiträgt, benutzerfreundlichere und intuitivere Webschnittstellen zu schaffen.

Bei der Durchführung der Benutzermodellstudie wurden verschiedene Benutzereigenschaften wie Alter, Geschlecht, Nationalität, Bildungsniveau und Sprache berücksichtigt [1]. Besondere Aufmerksamkeit wurde den Nutzerinteressen gewidmet, die eine wichtige Rolle bei der Gestaltung des Nutzerprofils spielten. Die Forscher stellten fest, dass eine Behinderung ebenfalls ein Schlüsselmerkmal bei der Erstellung von IUIS ist. Die Korrelationen zwischen Hobbys und Gerät sowie Behinderung und Qualifikationsniveau bestätigen, wie wichtig es ist, den emotionalen Zustand und die Interessen des Benutzers bei der Festlegung seines Profils zu berücksichtigen.

Clustering- und Klassifizierungsmethoden zur Analyse des Nutzerverhaltens werden für die Erstellung personalisierter Schnittstellen verwendet. Mit diesen Methoden lassen sich die einzigartigen Merkmale von Nutzergruppen ermitteln, was wiederum die automatische Anpassung von Schnittstellen an die individuellen Präferenzen jedes Nutzers erleichtert.

Technologien zur Anpassung von Webschnittstellen beruhen auf der Verwendung von Modellen des Nutzerverhaltens, um Mechanismen zu schaffen, mit denen Schnittstellen auf die individuellen Bedürfnisse jedes Nutzers zugeschnitten werden können. Eine Möglichkeit, dieses Ziel zu erreichen, ist die Personalisierung von Inhalten und Funktionen, die sich auf Informationen über den Benutzer und seine persönlichen Vorlieben stützt. Eine andere Anpassungstechnik besteht darin, die Schnittstelle in Echtzeit auf der Grundlage der Benutzeraktivität dynamisch zu verändern. Ein wichtiger Bestandteil der Anpassungstechniken ist die Sammlung und Analyse von Daten über das Nutzerverhalten, die es ermöglichen, genauere Modelle zu erstellen, um den Anpassungsprozess von Webschnittstellen zu verbessern.

In einer aktuellen Studie [2] wird die Bedeutung der Benutzerfreundlichkeit für Benutzer mit Behinderungen und geringen Lese- und Schreibkenntnissen erörtert. Die Implementierung einer generativen Benutzeroberfläche (GUI) kann die Erklärung komplexer Themen erheblich vereinfachen und Nutzern mit Behinderungen helfen. Die Umstellung auf eine generative Benutzeroberfläche der zweiten Generation kann die Arbeitsweise von UXExperten revolutionieren. Sie wird das Benutzererlebnis durch eine stärkere Personalisierung erheblich verbessern.

Eines der wichtigsten Ergebnisse unserer Arbeit war die Entwicklung grundlegender Algorithmen zur Anpassung von Schnittstellen, die einfache Modelle des Nutzerverhaltens verwenden. Bei der Entwicklung unseres Projekts haben wir aktiv fortgeschrittene Technologien für maschinelles Lernen und künstliche Intelligenz eingesetzt. Unser Ziel ist es, flexiblere und vielseitigere Modelle des Nutzerverhaltens zu entwickeln, die sich an unterschiedliche Situationen und Bedürfnisse anpassen können. Dies wird uns eine genauere und effizientere Anpassung von Webschnittstellen an individuelle Präferenzen und den Nutzungskontext ermöglichen.

Unsere Arbeit umfasst nicht nur die Entwicklung von Algorithmen, sondern auch die Erforschung neuer Optimierungstechniken und die

Verbesserung von Anpassungsalgorithmen. Wir sind bestrebt, innovative Lösungen zu schaffen, die den Bereich der Schnittstellengestaltung revolutionieren und die Benutzerfreundlichkeit von Webanwendungen für alle Nutzer verbessern können.

**Referenzen:**

1. Gaspar A., Gil M., Panach I., Romero V. Towards a general user model to develop intelligent user interfaces // Multimedia Tools and Applications. – 2024
2. Nielsen, J. Accessibility Has Failed: Try Generative UI = Individualized UX / Jakob Nielsen [Elektronische Ressource] // Substack. 2024. URL: <https://jakobnielsenphd.substack.com/p/accessibility-generative-ui>

**Wissenschaftlicher Mitarbeiter:** Kandidat der technischen Wissenschaften, außerordentlicher Professor M.A. Bakaev.

**Sprachberaterin:** Hochschuldozentin, L.F. Luchikhina.

**Entwicklung eines Geräts zur Überwachung der orthopädischen Körperhaltung**

**Sergey Kharin**, Staatliche Technische Universität Nowosibirsk, Nowosibirsk, Russland, [sergey.harin0304@mail.ru](mailto:sergey.harin0304@mail.ru)

***Annotation:** Der Beitrag beschreibt eine neue Methode zur Beurteilung der menschlichen Haltung mit Hilfe eines elektronischen Geräts. Das Gerät ist für die Aufrechterhaltung einer korrekten orthopädischen Haltung erforderlich. Das Gerät selbst besteht aus einem Sensor und einem Verstärker. Der Sensor ist an einem Netzhemd befestigt und reagiert auf die Konvergenz der Schultern, und das Signal des Sensors wird dem Verstärker zugeführt. Der Artikel beschreibt die zur Herstellung des Geräts verwendeten Materialien und Methoden.*

***Schlüsselwörter:** Orthopädie, Körperhaltung, Sensor, Gerät.*

Die Körperhaltung ist die gewohnheitsmäßigste Position des Körpers im Raum. Jeder Mensch hat seine eigene Haltung, aber nicht jeder hat die richtige Haltung [1]. Die typischste Manifestation der abnormalen Haltung ist die Neigung des Kopfes nach vorne, das Herabhängen und Konvergieren der Oberarme, die Vorwölbung der Schulterblätter und die Vorwölbung der vorderen Bauchwand [1-2].

Eine Fehlhaltung kann zu Problemen im gesamten Körper führen. Die Ausbildung einer korrekten orthopädischen Haltung ist eng mit der Erziehung des Kindes verbunden. Mit der Entwicklung des Kindes nimmt die Dauer der elterlichen Kontrolle ab, und die Selbstkontrolle in jungen Jahren ist nicht effektiv genug [2].

Ziel der Arbeit ist die Entwicklung eines Hardware-Systems zur aktiven Aufrechterhaltung der korrekten Körperhaltung durch den Patienten auf der Grundlage von Biofeedback.

Der Sensor besteht aus einem flexiblen Substrat, auf dem die Wägezellen montiert sind. An den Rändern des Substrats sind zwei Magnete angebracht, von denen einer fest mit der Plattform verbunden ist, während sich der zweite bewegen kann. Durch seine Dehnung verändert sich der Querschnitt des Substrats, was von den Halbleiterelementen aufgenommen wird und zu einer Änderung ihres elektrischen Widerstands führt. Nachdem das Substrat in den Ausgangszustand zurückversetzt wurde, ist der Widerstand der Halbleiter wieder normalisiert.

Als Sensor werden dehnungsempfindliche Halbleiterelemente verwendet. Abb. 1 zeigt deren Verschaltung in Form einer Halbbrückenschaltung.

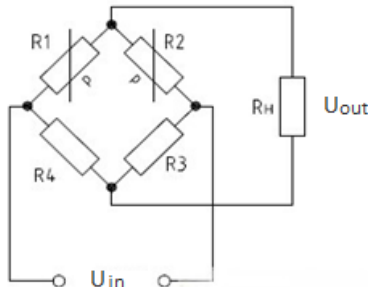


Abbildung 1 – Brückendiagramm für den Anschluss mehrerer Wägezellen: Halbbrücke

Die Widerstände  $R_1 = R_2 = 160$  Ohm sind Halbleiter-Wägezellen. Sie arbeiten auf Zug bzw. Druck. Mit einem der verbleibenden Widerstände  $R_3 = R_4 = 200$  Ohm wird die Brücke abgeglichen, um die Diagonalspannung an der ursprünglichen Sensorposition auf null zu stellen. Ein Signal wird von der Diagonale abgenommen, deren Punkte mit der Last verbunden sind ( $R_H$ ).

Durch Ändern der Widerstände  $R_1$  und  $R_2$  verringert sich das Potenzial des Punktes auf der Diagonale und die Spannung der Diagonalbrücke ändert sich. Zur Kalibrierung des Sensors wird parallel zum Widerstand  $R_1$  ein variabler

Widerstand eingefügt, mit dem die Potenzialdifferenz gegen Null verschoben wird.

Die Magnete des Sensors sind an einem Netzhemd im Bereich zwischen den Schulterblättern auf der Höhe der Wirbel Th3-Th5 angebracht. Wenn die Schultern zusammengebracht werden und die Wirbelsäule gebeugt wird, vergrößert sich der Abstand zwischen den Schulterblättern, der Stoff des Hemdes wird gedehnt, der Sensor nimmt diese Veränderungen wahr und erzeugt ein kleines elektrisches Signal, das anschließend einem Operationsverstärker mit einer Verstärkung von 100-500 Einheiten oder ~50 dB zugeführt wird.

Als OP-Verstärker wird ein LM358-Mikroschaltkreis verwendet. Das verstärkte Signal wird an den aktiven Summer weitergeleitet. Die Verstärkerschaltung ist in Abb. 2 dargestellt. Die Widerstände sind:  $R_1 = R_3 = 100 \text{ k}\Omega$ ,  $R_3 = R = R_{46} = R_7 = 1 \text{ k}\Omega$ ,  $R_2 = 20 \text{ k}\Omega$ . Die Schaltung wird von zwei Lithiumbatterien des Typs CR2032 mit einer Gesamtspannung von 6 V gespeist.

Die beschriebenen Daten sind das Ergebnis meiner Forschungstätigkeit. Die Experimente haben gezeigt, dass die Empfindlichkeit des Geräts bei einer minimalen Änderung der Verstärkung erheblich verbessert wird.

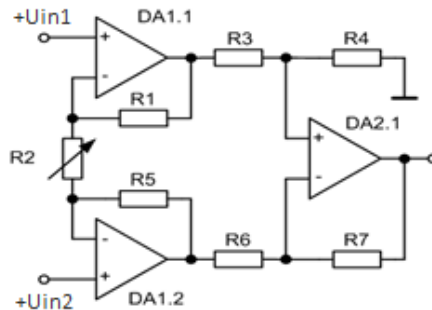


Abbildung 2 – Schematische Darstellung des Instrumentalverstärkers an drei OP-Verstärker

Zusammenfassend lässt sich sagen, dass dieses Gerät eine präzise Steuerung des Geräts ermöglicht und das Potenzial für einen stabilen Betrieb zeigt, wenn Faktoren wie die Ausgangshaltung des Patienten und anthropometrische Parameter variieren.

Das entwickelte Gerät ist vollständig analog. Seine Einfachheit kann als Vorteil bei der Realisierung und Nutzung des Projekts angesehen werden. Einer der Vorteile der aktuellen Version des Geräts ist das Vorhandensein eines Potentiometers zur Einstellung der Empfindlichkeit des Geräts. Für die Zukunft ist eine grundlegende Überarbeitung der aktuellen Version geplant, die durch eine mobile Anwendung zur drahtlosen Signalübertragung und Steuerung des Gerätebetriebs ergänzt werden soll.

#### **Referenzen:**

1. Nigamad'yanov N.R., Cykunov M.B., Ivanova G.E., Luk'yanov V.I. Izuchenie osanki u detej shkol'nogo vozrasta po dannym opticheskoy topografii spiny. Vestnik travmatologii i ortopedii im N.N. Priorova. 2019; (4):43 45. [Nigamadianov N.R., Tsykunov M.B., Ivanova G.E., Lukyanov V.I. Untersuchung der Körperhaltung bei Kindern im Schulalter anhand der Daten der optischen Topographie des Rückens. Vestnik Traumatologii i orthopaedii im N.N. Priorov. 2019; (4):43 45]

2. Endolov V.V., Birchenko N.S., Osobennosti motornoj sostavlyayushchej mezhpolusharnoj asimmetrii mozga u detej so skoliozom // Fundamental'nye issledovaniya. – 2005. – № 4. – S. 13-15. [Endolov V.V., Birchenko N.S., Merkmale der motorischen Komponente der interhemisphärischen Gehirnasymmetrie bei Kindern mit Skoliose // Grundlagenforschung. – 2005. – Nr. 4. – S. 13-15]

**Wissenschaftlicher Mitarbeiter:** A.V. Gladkov, Doktor der medizinischen Wissenschaften, Professor.

**Sprachberaterin:** L. F. Luchikhina, Cheflektorin.

### **Entwicklung einer auf Computer Vision basierenden mobilen Software zur Bewertung der Rindfleischqualität**

**Irina Kabanova**, Staatliche technische Universität Nowosibirsk,  
Nowosibirsk, Russland, [kabanova\\_3@mail.ru](mailto:kabanova_3@mail.ru)

***Annotation:** In diesem Artikel geht es um die Entwicklung einer auf Computer Vision basierenden mobilen Software zur Bewertung der Qualität des Rindfleisches. Das Hauptergebnis ist die Entwicklung eines Plans für die Erstellung einer mobilen Software.*

***Schlüsselwörter:** Rindfleisch, mobile Software, künstliche Intelligenz, Computer Vision.*

Das Rindfleisch gehört zu den tierischen Produkten mit hohem Nährwert, da es Kohlenhydrate, Proteine, Fette, Vitamine und Mineralstoffe enthält. Daher muss die Qualität des Rindfleisches auf dem richtigen Niveau gehalten werden, damit die Verbraucher gutes Rindfleisch von guter Qualität erhalten.

Die meisten Menschen haben jedoch keine professionelle Vorstellung von Rindfleisch, um seine Qualität zu bewerten. Darüber hinaus erfolgt die Bewertung der Rindfleischqualität in der Regel visuell durch den Vergleich von tatsächlichem Rindfleisch und Referenzbildern jeder Rindfleischklasse. Dieses Verfahren hat Nachteile, da es subjektiv und zeitaufwändig ist. Daher ist es wichtig, ein automatisiertes System zu entwickeln, das auf der Bildverarbeitung basiert und die Qualität des Rindfleisches bestimmen kann.

Künstliche Intelligenz erlebt in letzter Zeit ein rasantes technologisches Wachstum. Künstliche Intelligenz wird nicht nur in industriellen Bereichen aktiv eingesetzt, sondern auch in mobilen Anwendungen, die täglich von vielen Menschen genutzt werden.

Moderne Smartphones sind mit relativ hochwertigen Kameras ausgestattet und verfügen über eine ausreichende Rechenleistung. Dadurch ist es möglich, eine mobile Software zur Bewertung der Qualität von Lebensmitteln mithilfe Computer Vision zu entwickeln [1]. Die Computer Vision Technologie entspricht den Funktionen des menschlichen Sehens durch elektronische Bildwahrnehmung und Bildauswertung.

Das Ziel dieser Arbeit ist die Entwicklung einer auf künstliche Intelligenz und Computer Vision basierenden mobilen Software zur Bewertung der Rindfleischqualität. Die in diesem Artikel vorgeschlagene Software soll dem gewöhnlichen Verbraucher helfen, eine Entscheidung über den Kauf von Rindfleisch zu fassen. Die Software ermöglicht es dem Benutzer, ein Foto von Rindfleisch mit künstlicher Intelligenz zu analysieren und Informationen über seine Qualität zu erhalten.

Die Software wird eine Client-Server-Architektur für Echtzeitbetrieb haben. Der Client-Teil soll das Bild mit der Smartphone-Kamera aufnehmen, das Bild über das HTTP-Protokoll an den Server übertragen, die Verarbeitungsergebnisse auf dem Server abrufen und dem Benutzer anzeigen. Der Server verwendet das aufgenommene Bild, um den Frischegrad und den Marmorierungsgrad des Rindfleisches zu bestimmen und übermittelt die Ergebnisse an den Client.



Die Hauptfunktionen der Software sind:

- Klassifizierung der Frische;
- Bewertung des Marmorierungsgrades

Die Frische von Rindfleisch wird in drei Kategorien unterteilt: gut, mittel und schlecht. Unter Marmorierung versteht man den Fettanteil in einem Stück Rindfleisch sowie wie gleichmäßig das Fett verteilt ist. Je nach diesen Indikatoren wird das Rindfleisch in die Kategorie A, B oder C eingestuft.

Für die Entwicklung des Programms wurde Python als Programmiersprache ausgewählt. Die Frische des Rindfleischs wird mithilfe eines maschinellen Lernmodells bestimmt. Tensorflow, eine Open-Source-Bibliothek für maschinelles Lernen, wird zum Erstellen und Trainieren des Modells verwendet.

Um die Marmorierung von Rindfleisch zu messen, wird OpenCV verwendet – eine offene Bibliothek für die Arbeit mit Computer Vision-Algorithmen, maschinellem Lernen und Bildverarbeitung. Diese Bibliothek eignet sich auch für die Bildsegmentierung. In diesem Fall ist eine Segmentierung erforderlich, um das Fleisch vom Hintergrund und das Fett vom Fleischteil zu trennen [2].

Die weitere Entwicklung der Software umfasst die folgenden Schritte:

1. Auswahl einer Bildsegmentierungsmethode;
2. Auswahl eines maschinellen Lernmodells;
3. Training des Modells;
4. Entwicklung der Client- und Serverteile der Software;
5. Bereitstellen eines Modells;
6. Testung.

#### **Referenzen:**

1. Kaja Kalinowska Smartphones as tools for equitable food quality assessment / Kaja Kalinowska, Wojciech Wojnowski, Marek Tobiszewski et al. // Trends in Food Science & Technology. – 2021. – Vol. 111 – P. 271-279.
2. Kusworo Adi Beef Quality Identification Using Thresholding Method and Decision Tree Classification Based on Android Smartphone // Journal of Food Quality. – 2017. – DOI: 10.1155/2017/1674718.

**Wissenschaftlicher Mitarbeiter:** A. F. Aleynikov, Doktor der technischen Wissenschaften, Professor

**Sprachberaterin:** L.F. Luchikhina, Cheflektorin

## **Erforschung verschiedener Arten von elektrischen Energiespeichern**

**Pavel Mirganov**, Staatliche Technische Universität Nowosibirsk,  
Novosibirsk, Russland, [p.mirganov@yandex.ru](mailto:p.mirganov@yandex.ru)

***Annotation:** Überblick über verschiedene Arten von elektrischen Energiespeichern mit statischer und dynamischer Wirkzone. Es werden Beispiele für die Anwendungsbereiche der betrachteten Speicher angeführt. Es wird eine vergleichende Tabelle der Eigenschaften der betrachteten Speicher gegeben.*

***Schlüsselwörter:** Elektrische Energiespeicherung, Batterie, Superkondensator, supraleitende induktive Speicherung, Schwungrad.*

Elektrische Energiespeicher können in zwei Hauptkategorien unterteilt werden: statische Speicher, zu denen elektrochemische, induktive und kapazitive Speicher gehören. Und Speicher mit einer dynamischen aktiven Zone, wie z. B. elektromechanische Geräte.

Schauen wir uns einige Fahrten mit einer statischen aktiven Zone an: Lithium-Ionen-Batterien.

Dieser Batterietyp ist einer der am weitesten verbreiteten. Lithium-Ionen-Batterien haben eine hohe spezifische Energiekapazität, die Energiedichte moderner Batterien liegt heute bei  $265 \frac{W \cdot h}{kg}$ , sie zeichnen sich außerdem durch tiefe Entlade-Ladezyklen (70-80 %) und das Fehlen eines Memory-Effekts aus. Lithium-Ionen-Batterien sind in verschiedenen Anwendungen weit verbreitet, aber seit 2018 sind Elektrofahrzeuge zum Hauptverbraucher von Lithium-Ionen-Batterien geworden, wobei die Nachfrage um 50 % pro Jahr steigt. Der Elektroverkehr ist inzwischen der am schnellsten wachsenden Sektor und übertrifft in Bezug auf Wachstum und Investitionen sogar die Wind- und Solarenergie.

Superkondensatoren haben eine geringere spezifische Energiekapazität von bis zu  $4 \frac{W \cdot h}{kg}$ , dafür aber eine höhere spezifische Leistung von bis zu  $10 \frac{kW}{kg}$ , wodurch Superkondensatoren optimal für den Betrieb bei starken und signifikanten Leistungsänderungen und zur Stabilisierung der Stromparameter geeignet sind. In jüngster Zeit wurden unterbrechungsfreie Stromversorgungssysteme auf der Grundlage von Superkondensatoren in der Energiewirtschaft aktiv eingeführt, da sie im Vergleich zu Blei- und Lithium-Ionen-Batterien eine sicherere Lösung darstellen.

Im Gegensatz zu wiederaufladbaren Batterien verwenden sie keine chemische Reaktion zur Speicherung und Freisetzung von Energie, was sie sicherer und umweltfreundlicher macht. Darüber hinaus neigen Superkondensatoren nicht zur Selbstzerstörung und sind explosionsicher. Ebenfalls 2019 wurde in Russland ein Zelldesign patentiert, mit dem Superkondensatormodule eine spezifische Leistung von mehr als  $100 \frac{kW}{kg}$  bei einer spezifischen Energiedichte von bis zu  $10 \frac{W \cdot h}{kg}$  erreichen.

Zu den Speichergeräten mit dynamisch aktiver Zone gehören Speicherstationen, Druckluftspeichersysteme und elektromechanische Systeme mit einem Schwungrad. Die ersten beiden Typen zeichnen sich durch eine hohe Trägheit aus und erfordern besondere Bedingungen, was die Wettbewerbsfähigkeit solcher Laufwerke im Vergleich zu Trägheitslaufwerken verringert.

Es ist bekannt, dass kinetische Batterien mit Supermahoviki, bei denen das Schwungrad aus hochfestem Graphen material besteht, ein großes Potenzial haben. Diese Systeme können bis zu  $1200 \frac{kW}{kg}$  Energie speichern. Der Wirkungsgrad von Schwungradsystemen, die auf Graphenbändern basieren, erreicht 95%. Oft besteht die Hauptaufgabe von Schwungrädern darin, bei einem kurzzeitigen Ausfall bis zu 10 Sekunden ohne Strom zu versorgen. Ein weiterer Anwendungsbereich sind Pufferspeicher, um die Energieeffizienz von elektrischen Kränen, Baggern und anderen Geräten mit ungleicher Belastung zu verbessern.

Tabelle 1 enthält Vergleichsparameter verschiedener Laufwerkstypen.

Tabelle 1

Typ des Laufwerks Parameter	Lithium-Ionen-Batterien	Induktive Supraleiter-Speicher	Superkondensatoren	Handrade
Spezifische Energieintensität, (W·h)/kg	265	1000	10	1200
Leistungsdichte (W·h)/kg	0,34	27.7	100	Hängt von der elektrischen Maschine ab
Wirkungsgrad, %	95	98	95	95

Der Stromverbrauch steigt jedes Jahr mehr und mehr an, daher ist die Erforschung von elektrischen Energiespeichern eine wichtige Aufgabe. Dies erhöht die Speicherkapazität und die Qualität der Elektrizität. Dies wird auch dazu beitragen, die Emissionen von Treibhausgasen in die Atmosphäre zu reduzieren und die Energieeffizienz zu verbessern. Die Erforschung von elektrischen Energiespeichern wird dazu beitragen, die Stabilität und Zuverlässigkeit des Stromnetzes zu verbessern und die Abhängigkeit von fossilen Brennstoffen zu reduzieren. Dies könnte in Zukunft zu nachhaltigeren und umweltfreundlicheren Stromnetzen führen.

**Referenzen:**

1. E.K. Umbetkulov. Nakopiteli jelektrojenergii. Uchebnoe posobie / E.K. Umbetkulov, I.S. Sokolova. – Almaty: AUJeS im G. Daukeeva, 2022. – 79 s. [E.K. Umbetkulov. Stromspeicher. Lehrbuch / E.K. Umbetkulov, I.S. Sokolov. - Almaty: AUES im Daukeeva, 2022. - 79 s.]

2. S.P. Chudnovec. Nakopiteli jelektricheskoi jenerгии dlja sistem generirovanija jelektricheskoi jenerгии (analiticheskij obzor) / S.P. Chudnovec, S.A. Haritonov – Nauchnyj vestnik NGTU, 2013, № 1(50), 163-172s. [S.P. Chudnovets. Elektrische Energiespeicher für Systeme zur Erzeugung elektrischer Energie (analytische Überprüfung) / S.P. Chudnovets, S.A. Kharitonov - Wissenschaftlicher Bote der NGTU, 2013, № 1(50), 163- 172s.]

**Wissenschaftlicher Mitarbeiter:** S.V. Kuchak, Kandidat der technischen Wissenschaften.

**Sprachberaterin:** L.F. Luchikhina, Cheflektorin.

### **Etappen der Entwicklung einer spezialisierten Werkzeugmaschine für die Metallbearbeitung**

**Artemiy Neudakhin**, Staatliche Technische Universität Nowosibirsk, Nowosibirsk, Russland, t\_p16h@mail.ru

***Annotation:** In diesem Beitrag werden die Phasen der Entwicklung des allgemeinen Konzepts moderner spanender Werkzeugmaschinen betrachtet. Fehler, die in den frühen Phasen der Konstruktion gemacht werden, können zu einem erheblichen Anstieg der Arbeitskosten führen, um sie zu korrigieren. Daher ist die qualitative Erfüllung dieser Phase von entscheidender Bedeutung.*

***Schlüsselwörter:** Zerspanungsmaschinen, Bearbeitung, strukturell-kinematisches Schema.*

In der Welt der sich rasch entwickelnden Technologien spielen spezialisierte Werkzeugmaschinen eine Schlüsselrolle in den Produktionsprozessen. In diesem Beitrag werden die Entstehungsphasen des allgemeinen Konzepts der modernen spanabhebenden Werkzeugmaschinen untersucht. Diese Werkzeugmaschinen sind komplexe und technisch fortschrittliche Geräte, die eine hohe Produktivität und Qualität bei der Bearbeitung von Metallteilen gewährleisten.

In der ersten und wichtigsten Phase der Entwicklung neuer Zerspanungsmaschinen – der Phase der Erstellung eines technischen Vorschlags oder eines allgemeinen Konzepts des Entwurfsobjekts – erfolgt die Synthese des strukturellen und kinematischen Schemas und Layouts. Diese Phase ist von grundlegender Bedeutung und bestimmt die technische und wirtschaftliche Leistungsfähigkeit der künftigen Anlage. Fehler, die in

den frühen Phasen der Planung gemacht werden, können zu einem erheblichen Anstieg der Arbeitskosten führen, um sie zu korrigieren. Die Qualität dieser Phase ist daher entscheidend.

Die Analyse der Werkstückzeichnung, die technische Aufgabenstellung sowie die Anforderungen an die Maßgenauigkeit und die relative Positionierung der bearbeiteten Flächen, die Anforderungen an die Oberflächenrauheit, das Material des Werkstücks, die geforderte Produktivität, die Nomenklatur der Schneidwerkzeuge, der Automatisierungsgrad bzw. die Art der Fertigung, die Flexibilität und die technischen Möglichkeiten der geplanten Anlage bestimmen die Ausgangsdaten für die Synthese des strukturell-kinematischen Schemas und Layouts.

Die Auswahl einer rationellen Bearbeitungsmethode, die Festlegung der Struktur der Elementarbewegungen - all dies ist Teil des Prozesses der Ausarbeitung des ursprünglichen Konzepts der Ausrüstung. Die Arbeit, die der Konstrukteur bei der Behandlung dieses Themas leistet, ist analytischer Natur.

Die Komplexität dieser Aufgabe erfordert eine gründliche Kenntnis der Theorie der Oberflächenbearbeitung, der Schneidwerkzeuge und der Metallbearbeitungsgeräte. Es ist wichtig, die Art und Anzahl der Betätigungsbewegungen, die rationelle Auslegungslösung sowie die kinematischen Beziehungen und mögliche Anpassungen zu bestimmen. Diese Phase der Entwicklung des strukturellen und kinematischen Schemas und der Auslegung ist sehr verantwortungsvoll, da in dieser Phase fast alle zuvor aufgeführten Anforderungen der technischen Spezifikation festgelegt werden und darüber hinaus die Konstruktionskomplexität der Werkzeugmaschine, die sich in der Herstellbarkeit ihrer Herstellung und Reparatur manifestiert, die Arbeitsintensität der Einstellung der Parameter der Ausführungsbewegungen im Prozess der Bedienung der Ausrüstung, die die Produktivität beeinflusst.

Es ist notwendig, die Art und Anzahl der Ausführungsbewegungen zu bestimmen. Die exekutiven Bewegungen der Knotenpunkte werden aus elementaren Bewegungen gebildet. Sie können einfach und komplex sein. Bei der Bestimmung der Zusammensetzung der exekutiven Bewegungen wird die Notwendigkeit erkannt, elementare Bewegungen, die in komplexen

Bewegungen enthalten sind, zu koordinieren oder elementare Bewegungen als einfache exekutive Bewegungen zu akzeptieren.

Der nächste Schritt besteht darin, die rationellste Layout-Lösung zu finden. Konzeptionelle Suche nach der optimalen Lösung für die relative Position, die Art der Bewegung und die räumliche Ausrichtung der wichtigsten Maschinenkomponenten.

Die Auslegung der Anlage wirkt sich auf die Qualitätsindikatoren, die Möglichkeit der Automatisierung von Vorgängen, die Benutzerfreundlichkeit für den Bediener, die Produktivität sowie die Lagerung des Transports und der Installation der Maschine, das Gewicht, das die Produktionsfläche einnimmt, und die Übereinstimmung des Aussehens mit den modernen Anforderungen des technischen Designs aus. In dieser Phase werden also nicht nur die Struktur und die Kinematik des Geräts bestimmt, sondern auch seine allgemeine Effizienz und Funktionalität.

Es ist notwendig, das Problem der Platzierung der Einstellorgane für die Parameter der Ausführungsbewegungen zu lösen. In dieser Phase der Synthese des strukturellen und kinematischen Schemas werden die Einstellorgane der einstellbaren Parameter der Ausführungsbewegungen, die Wandler des Bewegungstyps und die Schalter in den kinematischen Kreisen installiert.

Die Analyse des sich daraus ergebenden strukturell-kinematischen Diagramms und die Korrektur auf der Grundlage der festgestellten Mängel ermöglicht die Verbesserung des Konzepts und die Vorbereitung der Ausrüstung für die nachfolgenden Planungsphasen. In dieser Phase ist es notwendig, die Mechanismen darzustellen, die die festgelegten Funktionen erfüllen werden, d. h. anstelle der herkömmlichen Bezeichnungen der Schemaelemente ist es notwendig, den strukturellen Aufbau zu sehen. Gleichzeitig wird die Möglichkeit analysiert, die Anzahl der kinematischen Ketten und Organe für die Einstellung der Parameter der ausführenden Bewegungen zu reduzieren und die Konstruktionsformeln für die Einstellung zu vereinfachen. Zu diesem Zweck werden detaillierte Gleichungen des kinematischen Gleichgewichts für alle elementaren Bewegungen erstellt. Die kompetente Ausführung dieser Schritte gewährleistet die erfolgreiche Entwicklung und Herstellung von hocheffizienten Zerspanungsanlagen.

Abschließend ist festzustellen, dass die Konstruktion moderner spanender Werkzeugmaschinen ein komplexer und verantwortungsvoller Prozess ist, der eine sorgfältige Analyse und Synthese des strukturellen und kinematischen Schemas erfordert. Die Qualität dieser Phase wirkt sich erheblich auf die technische und wirtschaftliche Leistung der geschaffenen Ausrüstung sowie auf ihre Produktivität und die Qualität der Bearbeitung von Metallteilen aus. Fehler, die in den frühen Phasen der Konstruktion gemacht werden, können zu einem starken Anstieg der Arbeitskosten für die Korrektur führen. Daher ist es wichtig, eine gründliche Analyse der Anforderungen an die Anlage durchzuführen, rationelle Bearbeitungsmethoden auszuwählen, die Art und Anzahl der ausführenden Bewegungen zu bestimmen sowie das strukturelle und kinematische Schema anzupassen und zu verfeinern, um optimale Ergebnisse zu erzielen. All diese Maßnahmen werden es ermöglichen, effiziente und technologisch fortschrittliche Zerspanungsmaschinen zu schaffen, die den modernen Produktionsanforderungen entsprechen.

#### **Referenzen:**

1 Kinematische Berechnung des Hauptantriebs von spanenden Werkzeugmaschinen Lehrbuch Yu S Chyosov - Novosibirsk Izd-vo NSTU 2013 - 80 s [Kinematische Berechnung des Hauptantriebs von spanenden Werkzeugmaschinen: Lehrbuch / Yu.S. Chyosov. - Novosibirsk: Izd-vo NSTU, 2013. - 80 c.]

**Wissenschaftlicher Mitarbeiter:** V.Y. Skiba, Hochschuldozentin.

**Sprachberaterin:** L.F. Luchikhina, Hochschuldozentin.

### **H-Brücke-Steuersystem im Notbetrieb**

**Egor Schweigert**, Staatliche Technische Universität Nowosibirsk,  
Nowosibirsk, Russland, [shveygert.egor@gmail.com](mailto:shveygert.egor@gmail.com)

***Annotation:** Der Beitrag betrachtet mögliche Varianten der Sternpunktverschiebung in Notbetriebsarten mit kaskadierter Einbindung von H-Brücken.*

***Schlüsselwörter:** Halbleiterumrichter, Inventor.*

Eine der Entwicklungsrichtungen moderner Wechselstromantriebe ist der Übergang zur automatischen Regelung der Rotorwinkelgeschwindigkeit von



Hochleistungsmotoren im Bereich von Einheiten bis zu mehreren zehn Megawatt. Diese Motoren werden mit Frequenzumrichtern betrieben, die auf der Grundlage einer mehrstufigen Topologie realisiert sind. Dabei werden drei grundlegende Arten von autonomen Spannungsinvertiern unterschieden: mit fester Neutralpunkt [1], mit schwimmenden Kondensatoren [1] und mit kaskadierter oder sequentieller Einbeziehung von H-Brücken [1]. In letzterem Fall verbessert sich die harmonische Zusammensetzung der verbrauchten Ströme, es gibt ein modulares Montageprinzip der Leistungsstufe und eine große Anzahl von Ebenen, wodurch diese Konfiguration die größte Verbreitung in praktischen Anwendungen gefunden hat.

Um die Zuverlässigkeit elektromechanischer Systeme dieses Typs zu erhöhen, wenn Elemente im Steuer- oder Leistungsteil des Halbleiterwandlers ausfallen, ist es wünschenswert, seine Funktionsfähigkeit zu erhalten. Dies kann durch die Einführung von Reservezellen, die Beibehaltung einer gleichen Anzahl von Arbeitsmodulen in allen drei Regalen oder durch die absichtliche Verschiebung des Neutralpunkt-Potentials erreicht werden [2]. Dieser Bericht befasst sich mit Fragen zur praktischen Umsetzung der letzten Methode zur Bildung eines symmetrischen Systems von dreiphasigen harmonischen Strömen des Motors.

Wie der Name dieser Topologie zeigt, besteht das Leistungsschema jeder Phase aus der sequentiellen Verbindung von  $n$  identischen H-Brücken, die über ein Gleichstromglied und einen Gleichrichter mit der individuellen Sekundärwicklung des Transformators verbunden sind. Das Schalten der Leistungsschlüssel des Inverters erfolgt gemäß der PWM bei Nullmodulation und Phasenverschiebung des Referenzsignals in jedem der Leistungsmodule um  $180^\circ/n$  [3].

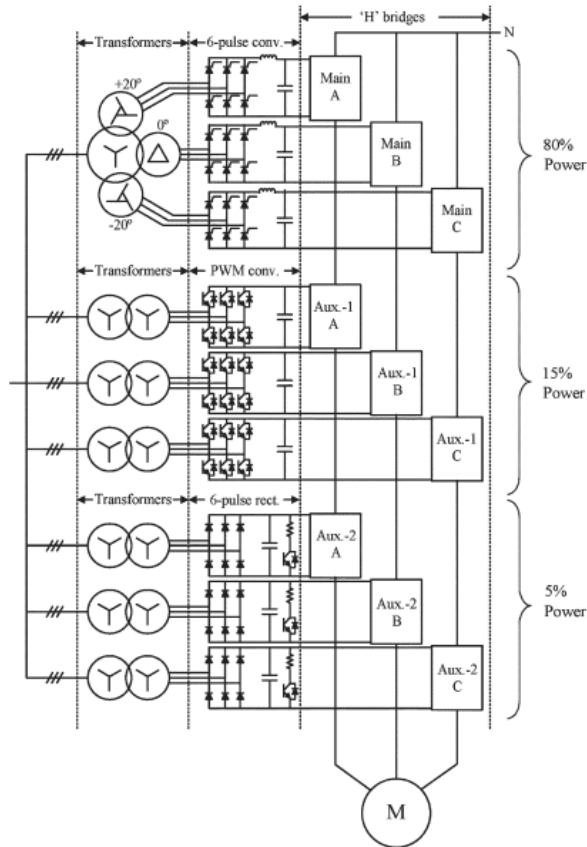
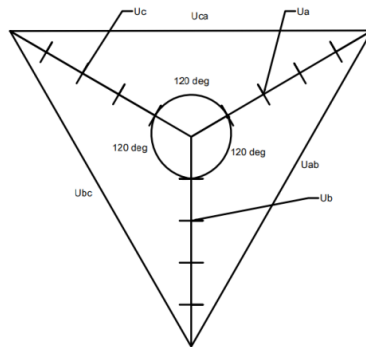


Abbildung 1. Funktionsdiagramm des mehrstufigen Wandlers mit kaskadierten H-Brücken

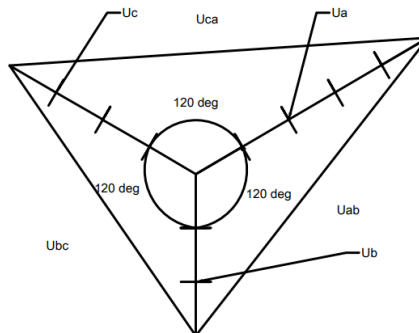
Im störungsfreien Zustand des Leistungswandlers werden lineare Spannungen an seinem Ausgang erzeugt, deren Vektordiagramm ein gleichseitiges Dreieck mit den Seiten  $|u_{ab}| = |u_{cb}| = |u_{ac}|$  bildet, wie in Abbildung 2 gezeigt.



*Abbildung 2. Vektordiagramm in Form eines gleichseitigen Dreiecks*

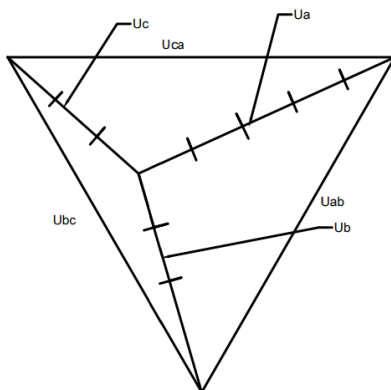
Aus der obigen Abbildung ist ersichtlich, dass drei Vektoren faseriger Spannungen relativ zum Neutralpunkt angeordnet sind, deren Länge durch die Anzahl der Zellen im Regal bestimmt wird. Zwischen den Enden dieser Vektoren werden Vektoren linearer Spannungen aufgebaut. Standardmäßig betragen die Winkel zwischen den Phasen 120 Grad. Somit entsteht bei gleicher Amplitude der phasigen Spannungen ein gleichseitiges Dreieck.

Jedoch, wenn eines oder mehrere Regale ausfallen, nimmt die Amplitude der phasigen Spannung ab, wodurch die lineare Spannung unsymmetrisch wird, wie in Abbildung 3 illustriert.



*Abbildung 3. Spannungsdreieck mit ausgefallenen Regalen*

Die Idee, Ströme durch Verschiebung des Neutralpunkt-Potentials zu symmetrieren, besteht darin, die linearen Spannungen durch Änderung des Winkels zwischen den Phasen auszugleichen, wie in Abbildung 4



dargestellt.

*Abbildung 4. Gleichseitiges Dreieck mit verschobenem Neutralpunkt.*

Die technische Umsetzung der Verschiebung des Neutralpunkt-Potentials des Wandlers mit kaskadierten H-Brücken kann durch Änderung des Übertragungsfaktors des PWM-Kanals, Anwendung einer Nullkomponente der Spannung oder Verschiebung von Spannungsvektoren um festgelegte Winkel erfolgen.

### Referenzen:

1. Nos O.V. Algoritmy upravleniya mnogourovnevym invertorom napryazheniya s kaskadnym vklyucheniem N-mostov v avarijnom rezhime raboty / Nos O.V., Dybko M.A., Nos N.I.// Elektrotehnika. - 2021. - №12. - S. 37-42 [Nos, O.V. Regelungsalgorithmen des Multilevel-Spannungswechselrichters mit der Kaskadeneinbindung der H-Brücken im Notbetriebsmodus / Nos, O.V.; Dybko, M.A.; Nos, N.I.// Elektrotehnika. - 2021. - №12. - C. 37-42.]
2. Mariusz Malinowski A survey on Cascaded Multilevel Invertors / Mariusz Malinowski, Jose Rodriguez, Marcelo A. Perez. // IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS. - 2010. - №7. - C. 2197-2203.
3. Pablo Lezanna Extended Operation of Cascade Multicell Converters Under Fault Condition / Pablo Lezanna, Gabriel Ortiz. IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS. - 2009. - №7. - C. 2697-2700.

**Wissenschaftlicher Mitarbeiter:** Nos O. V., Doktor der technischen Wissenschaften, außerordentlicher Professor.

**Sprachberaterin:** L. F. Luchikhina, Cheflektorin.

## **Optimierung der Getriebeparameter für den Geländewagen «Predator 3930»**

**Richard Eyrich**, Staatliche Technische Universität Nowosibirsk,  
Nowosibirsk, Russland, Novosibirsk, Russia, [richard.eirih@yandex.ru](mailto:richard.eirih@yandex.ru)

**Ilya Lanshakov**, Staatliche Technische Universität Nowosibirsk,  
Nowosibirsk, Russland, Novosibirsk, Russia, [mr.ramzonov@gmail.com](mailto:mr.ramzonov@gmail.com)

***Annotation:** Diese Arbeit ist eine Verallgemeinerung von Zwischenergebnissen der wissenschaftlichen Forschung. Ziel der Forschungsarbeit ist es, eine Methodik zur Berechnung der Leistungsmerkmale eines Geländewagens zu entwickeln und zusammenzustellen.*

***Schlüsselwörter:** Getriebe, Geländewagen, Niederdruckreifen, Übertragung*

Der Geländewagen ist ein hochgeländegängiges Fahrzeug für Fahrten in unwegsamem Gelände und bei fehlenden Straßen. Die hohe Geländetauglichkeit des Geländewagens wird durch Niederdruckreifen erreicht. Spezielle Räder sorgen für eine perfekte Bodenhaftung des Fahrzeugs, während die Reifen die Vegetation nicht zerstören, keine tiefen Spurrillen hinterlassen und sich leicht an verschiedene Unebenheiten anpassen.

«Predator-3930» wurde auf der Basis eines GAZ-Fahrzeugs gebaut. Ein wichtiges Merkmal: Er bewegt sich auf dem Wasser durch die große Verschiebung der Räder. Aufgrund seiner relativ geringen Masse und der großen Radverschiebung bewegt sich der Geländewagen sicher im Schnee oder im sumpfigen Gelände und ist in der Lage, alle Schwierigkeiten des Terrains zu überwinden.

Die Optimierung eines jeden technischen Systems, einschließlich eines Geländewagens, ermöglicht die Bestimmung und Auswahl von Parametern, die in der Entwurfsphase die besten wirtschaftlichen, funktionellen und betrieblichen Eigenschaften bieten.



*Bild 1 - Predator-Geländewagen*

Gelöste technische Probleme:

1. Es ist notwendig, die Ursachen für den Ausfall des 5. Ganges des Getriebes des «CAMRY 30» zu ermitteln.
2. Berechnung der Getriebeübersetzungen, die den Eigenschaften des vorgeschlagenen Motors entsprechen, der in den Geländewagen eingebaut wird. Wenn die Eigenschaften des Motors geändert werden, müssen die Werte der Übersetzungsverhältnisse geändert werden.
2. Berechnung der Traktions- und Geschwindigkeitseigenschaften des Geländewagens.

Mögliche Fehlfunktionen des Schaltgetriebes

Vibrationen, Geräusche im Getriebe:

- Schwächung oder Beschädigung der Aufhängung des Motors und des Getriebes
- Verschlossene oder beschädigte Zahnräder und Lager
- Falsche Ölart wurde eingefüllt
- Unzureichender Ölstand

- Die Leerlaufdrehzahl des Motors ist nicht richtig eingestellt
- Schwierigkeiten beim Schalten und Schleifen beim Schalten:
- Kupplung nicht vollständig ausgekuppelt
- Unvollständige Haftung oder Abnutzung von Sicherungsringen und Synchronisationskonen
- Schwächung der Synchronisationsfedern
- Spontane Schaltvorgänge:
- Schaltgabeln verschlissen oder gebrochene Haltefedern

Das Übersetzungsverhältnis des ersten Ganges des Getriebes wird durch den angegebenen maximalen Fahrwiderstand bestimmt:

$$i_{K1} \geq \frac{G_a \cdot \psi_{max} \cdot r}{M_{e max} \cdot (1 - \beta) \cdot \eta \cdot i_k \cdot i_d^B}$$

$G_a$  – Gesamtgewicht des Fahrzeugs;

$\psi_a$  - Koeffizient des maximalen Fahrwiderstands;

$M_{e max}$  - maximales Motordrehmoment;

$\beta$  - einem Koeffizienten, der die Leistungsaufnahme für den Antrieb der Motorhilfsaggregate berücksichtigt;

$\eta$  - Wirkungsgrad des Getriebes ;

$i_k$  - Übersetzungsverhältnis des Getriebes im höchsten Gang;

$i_d^B$  – Übersetzungsverhältnis.

Traktion und dynamische Berechnung:

$$P_k = \frac{M_e \cdot (1 - \beta) \cdot i_k \cdot i_d^m \cdot i_o \cdot \eta}{r}$$

$M_e$  – Motordrehmoment;

$\beta$  - Koeffizient, der die Leistungsaufnahme für den Antrieb der Hilfsmechanismen des Motors berücksichtigt;

$i_k i_d^m i_o$  - Übersetzungsverhältnisse des Getriebes, des Verteilergetriebes bzw. des Hauptgetriebes;

$\eta$  - Wirkungsgrad der Kraftübertragung;

$r$  – Rollradius des Rades.

Zusammenfassend lässt sich sagen, dass im Rahmen dieses Projekts mögliche Übertragungsfehler identifiziert und die Traktions- und Geschwindigkeitseigenschaften des Geländewagens berechnet wurden.

**Referenzen:**

1. Snegobolotokhody Khishchnik-3930 [Elektronnyi resurs] Rezhim dostupa: <https://hishnikpro.ru/modelnyy-ryad/hischnik-3930-1/> (Data obrashcheniia 12.03.2024) [Schneemobile Predator-3930 [elektronische Ressource] Access: <https://hishnikpro.ru/modelnyy-ryad/hischnik-3930-1/> (Date 12.03.2024)]

2. Afanas'ev B.A., Belousov B.N., Gladov G.I. Proektirovanie polnoprivodnykh kolesnykh mashin T.1. Uchebnik dlia vuzov. – M.: MGTU, 2008. – 496 s. [Afanasiev B.A., Belousov B.N., Gladov G.I. Konstruktion von allradgetriebenen Radmaschinen T.1. Lehrbuch für Universitäten. – M.: MGTU, 2008. – p 496].

**Wissenschaftlicher Mitarbeiter:** E.D.Golovin, Kandidat der technischen Wissenschaften.

**Sprachberaterin:** L. F. Luchikhina, Cheflektorin.



**PROGRESS THROUGH INNOVATIONS**

**Proceedings 2024. XII International Academic and Research Conference  
of Graduate and Postgraduate Students**

**Труды XII международной научно-практической конференции аспирантов и  
магистрантов**

Ответственный редактор М.А. Салтымакова  
Выпускающий редактор И.П. Брованова  
Дизайн обложки А.В. Ладыжская

Налоговая льгота – Общероссийский классификатор продукции  
Издание соответствует коду 95 3000 ОК 005-93 (ОКП)

---

Подписано в печать 28.06.2024. Формат 60 × 84 1/16. Бумага офсетная. Тираж 20 экз.  
Уч.-изд. л. 9,99. Печ. л. 10,75. Изд. № 102. Заказ № 152. Цена договорная

---

Отпечатано в типографии  
Новосибирского государственного университета  
630073, г. Новосибирск, пр. К. Маркса, 20