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AIRCRAFT ENGINEERING

Proposals for Design of Long-flying Stratospheric Aircraft **Roman Semukhin**

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Abstract: Currently, many companies from different countries are working on the development of long-duration stratospheric aircraft. The main problem of creating such aircraft is to link long-term stratospheric flight with a design that must meet the requirements of strength and reliability.

Keywords: Stratospheric aircraft, pseudo-satellite, undulating wing, low Reynolds numbers, variable span wing, solar panels

Introduction

Stratospheric unmanned aerial vehicle applications of long-term flight is important for all developed countries where aircraft production is carried out [1]. The basis of energy saving in cruising flight at high altitude is high wing elongation ($\lambda > 20$) and low specific wing load (1–20 kg/m²). Creation of such a design is not an easy engineering task.

There are works devoted to the methodology of designing aeroplanes with a power plant operating on photovoltaic converters (PV). The results of these works result in a similar appearance of aircraft of this class. In the domestic work [2] as an example, the problem of creating a vehicle for monitoring the Earth surface powered by solar panels was solved. It is indicated that round-the-clock and year-round flight of such an aircraft (Fig. 1a) is possible only up to latitude 30°, as the average daily value of solar radiation should not fall below 120 W/m².

At low mass, this aircraft has a large geometric dimension due to low wing loading, which creates problems with structural strength and operational safety. The use of a folding wing [2] will increase the survivability of such aircraft during stratospheric flights.

Description of the selected design

The following scheme is proposed for a stratospheric aircraft: in flight, the wing increases in span stepwise from an altitude of 15 km, so that the area and span increase by a factor of 2.5–3, at the expense of which the speed decreases. Thus, the power required for flight at an altitude of 15 km is

reduced by a factor of 6.5–9 compared to the take-off and climb configuration. Such a concept has no analogues in the world.

As a result of analyzing the distribution of winds at different altitudes and regions of the Earth's surface [2], it was concluded that the cruising speed of a stratospheric aircraft should not be less than 30 m/s, otherwise it will not be able to overcome the winds at the barrage altitude (18–20 km) all year round. Therefore, the cruising speed of such an aircraft should be set from the beginning. Based on the analysis of the design of long-flying stratospheric aircraft [1, 2], it is possible to form a preliminary image of a stratospheric UAV with a sliding wing (Fig. 1b).

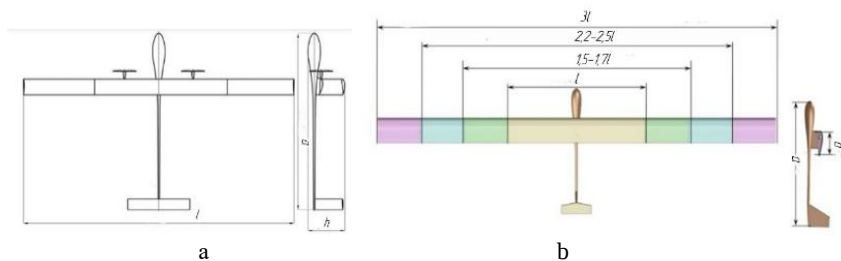


Figure 1 – a – Sketch of an aeroplane with a fixed wing and power supply from solar batteries [2], b – Sketch of an aeroplane with a sliding wing

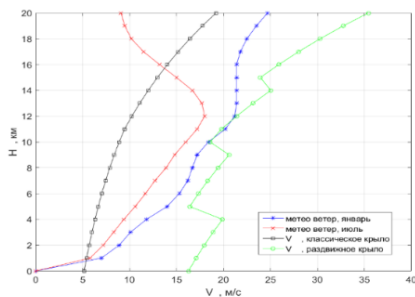


Figure 2 – Dependence of average wind speed and cruising speed of stratospheric aircraft with classic and sliding wing on altitude

Results

Figure 2 above shows the distribution of wind speed by altitude [2] for winter and summer solstice for the coordinates 50N. 80E and the dependence of cruising speed on altitude for stratospheric aircraft with classic and sliding wing.

To calculate the horizontal velocity as a function of altitude, it was assumed that the air density varies with altitude according to the law of the standard atmosphere and the values are tabulated from [2].

Conclusion

Stratospheric aircraft with a fixed wing and power supply from FEP and cruising speed of flight up to 30 m/s is not able to overcome the meteorological gauges on the entire trajectory of altitude gain and barrage altitude.

The technical solution to make an aircraft with a 3 times variable wingspan and a flight speed of over 30 m/s looks reasonable.

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Reverse Engineering in Aircraft Maintenance

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Abstract: This research is a summary of the future work dedicated to the problems of applicability of reverse engineering in the modern aircraft maintenance. The main

issue in the field of aircraft part repair is certification. Some ways to solve the problem are analyzed.

Keywords: reverse engineering, 3D scan, aircraft part

Introduction

Reverse engineering is a designing method, which is based on developing a new product on the base of its analogue. This method differs from that of copying by performing a complex analysis of the prototype with the implementation of changes in original construction. The necessity of the original construction modification is based on the difference in the country's standards and legislation base, development of the industry and the workers skilled rating. In the aircraft maintenance, this method is often implemented in two different ways:

1. Manufacturing minor parts with a life-limit.
2. Designing the specific repairs using technical documentation requirements.

However, in both methods, certification issues will occur, resulting from the safety requirements.

Goals of the work and objectives

The aim of the planned research is to investigate certification and technological issues of the method implementation for complicated aircraft repairs or parts replacement, including definition of the parts categories for which the method could be applied, as well as problems of keeping the original part geometry. To achieve this goal, the following tasks were determined:

1. Specific literature examination.
2. Analyzing technological standards, 3D-scanned models and maintenance organizations experience.
3. Specifying parts requiring rapid prototyping in the future work.

Materials and research methods

The research is based on the analysis of specific technological and scientific literature and practical materials. The sources include educational literature, aircraft industry standards, scientific articles. They provide information about modern rapid prototyping methods and technological

specifications for the equipment (3D scanners) and CAD systems. The validation of the information is performed by practical experience.

Research results and discussion

The main part of the reverse engineering is the product's prototyping and certification, including the derivation of the component responses. However, at the aircraft maintenance, time limits have significant importance because of the necessity to keep aircraft cost-effectiveness for operator. This leads to the requirement to reduce time for repair part designing, which results in the need of prototyping methods. Today, the rapid prototyping process could be based on the mechanical and 3D-scanning technologies. They have their own areas of applicability, but for almost all categories of the aircraft part it is 3D-scanning. This method combines three main advantages over mechanical dimension methods:

1. High speed of the dimensioning process.
2. Equipment portability.
3. High accuracy of the triangulating scanners.

The main problems of the mechanical dimensioning are the necessity of part derigging, a high cost of the control-dimensioning machines and their size for ensuring the accuracy required.

For aircraft maintenance, there is a necessity to perform scanning of installed details and surrounding environment for checking their geometry or constructing calculation models. For these purposes, 3D laser scanners are most applicable in handheld versions.

In the process of scanning, a cloud of points is constructed in the CAD system (most commonly used is CATIA system), where this raw object has to be reworked into a complete model. After finishing the CAD model, a detailed mock-up model is prepared for installing in the aircraft. The mock-up's main purpose is to check the model geometry before producing the repair part. In most cases, the model is prepared by using additive technologies or machined from domestic materials.

Certification of the repair or substitute parts is the second, and sometimes the largest phase of the designing process. The most trusting way to check the aircraft part characteristics is to perform the nature tests and an analytical prediction. However, in the realities of the Russian civil aviation and

industry, the lack of engineering information results in the fact that the most important aircraft parts could not be reversed with the required accuracy.

Conclusion

This study investigates the technological and certification challenges in the aircraft repair parts, produced by the reverse engineering method. The main process was described and the applicable methods of rapid prototyping were identified. In addition, the problems identified show that only the minor aircraft parts could be fully reversed by the implementation of advanced technologies in materials and manufacturing methods.

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Problems in Machining Equipment Made of Wood-laminated Plastics for Aircraft Parts Production

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Abstract: This article discusses the problems of CNC machining of balinite equipment and their solution in terms of tool form, clamping, machine, software and cutting rate requirements.

Keywords: balinite, CNC machine, CNC machining, protective coating, CAM, composite materials, wood laminate

In the 1930s and 1940s, impregnated wood composites such as balinite and Duramold were widely used in aircraft construction due to their strength-to-weight ratio and cost-effectiveness. Balinite, a laminated wood composite impregnated with phenolic resin, provides thermal and moisture resistance while maintaining the anisotropic properties of wood. Although aluminum alloys and carbon fiber have replaced these materials in aviation, balinite strength and lightness still make it suitable for creating equipment capable of replicating complex aircraft components. However, problems such as delamination and dimensional instability arise when machining balinite, affecting the quality of equipment. Despite the limited applications of balinite, there is currently a lack of comprehensive studies on its machining behavior, indicating the need for further research in this area.

Goals of the work and objectives

The purpose of this study is to investigate the technological problems associated with CNC machining of balinite and to analyze the critical factors affecting process stability, surface quality and tool life.

To achieve this goal, the following tasks are set:

1. To study the existing literature on the production of balinite and products from it
2. To analyze control programs and route documentation for production of equipment from balinite, to reveal the main problems arising at work with tools, equipment and machines at processing of balinite and to offer the optimum ways of their decision
3. To calculate optimal cutting rates

Materials and research methods

This study gives a literature review and analysis of existing control programs to assess CNC machining characteristics of balinite and similar wood-resin composites. Sources included historical manufacturing documents, composite machining research, and aircraft industry standards. Specific areas focused on included tool materials and coatings, workpiece clamping, cutting mode optimization based on thermal and mechanical responses, software requirements for control program development, and machine tool requirements like vibration resistance and spindle accuracy.

The findings were validated by practical experience from both old and modern aircraft projects and control program development practices.

Results

Balinite, a material known for its high abrasiveness and low thermal conductivity, creates machining problems related to tool wear and resin overheating. Specialty tool materials such as TiAlN, DLC-coated carbide or PCD are recommended [1] to address these issues, and controlling cutting edge sharpness is critical to prevent delamination. Tool geometry is less critical, therefore the use of mills with negative spiral direction for chip evacuation in large fixed workpieces may not be necessary. Balinite is dimensionally stable, but can be brittle or prone to edge cracking. This raises the issue of vibration during machining as it can cause micro-cracks or delamination, leading to rejects. To avoid these defects, it is recommended to use vacuum tables with rubber pads and mechanical clamps to securely fix and neutralize vibrations.

To achieve clean cutting without resin overheating, machining parameters such as selecting spindle speeds between 15,000-24,000 rpm, feed rates of 1,500-3,500 mm/min for roughing and 300-800 mm/min for finishing, a small depth of cut (1-3 mm), and opting for multiple passes over aggressive single-pass cutting are recommended [2]. Liquid coolant usage is discouraged due to potential composite damage, with compressed air, oil mist, or alcohol-based coolants as safe alternatives. Essential machine prerequisites include high spindle speeds, sturdy construction to prevent vibrations, HEPA dust extraction systems, and providing personal protective gear for operators. Composite-specific toolpaths and cutting modes in CAM software helps reducing delamination risks. Although post-production nondestructive testing is not mandatory, spot checks for surface cracks, delaminations, and dimensional accuracies improve equipment reliability.

Discussion

Machining balinite products poses unique challenges compared to working with natural wood and traditional aircraft materials like carbon fiber. Specialized fixing and precise process optimization are necessary due to the abrasive nature of resin-infused veneer, to prevent surface defects that can compromise dimensional accuracy and affect the final quality of aircraft

components. While non-destructive testing is not obligatory for tooling components, utilizing techniques like ultrasonic inspection can enhance the reliability of reusable equipment in serialized production settings. The research highlights that balinite has great potential for aircraft equipment production, requiring a deep understanding of its machining properties and the application of best practices in CNC machining for successful implementation.

Conclusion

This study investigates the technological challenges of CNC machining balinite for use in aircraft manufacturing equipment. Key issues identified include tool wear, delamination, and dimensional instability. Optimal cutting rates, tool selection, and machine requirements are proposed to address these problems.

The findings offer practical guidance for improving machining efficiency and quality. Future work may focus on experimental optimization of cutting parameters and evaluation of alternative cooling strategies.

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Maximum Lq-likelihood for Vacancy Analysis in Novosibirsk Region

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Abstract: This paper investigates the effectiveness of the maximum Lq-likelihood estimation (MLqE) method as an alternative to maximum likelihood estimation (MLE) for parameter estimation in gamma and inverse gamma distributions, especially with small to medium sample sizes. The study demonstrates that MLqE provides more accurate and reliable estimates, confirmed through simulations and analysis of salary data from the Novosibirsk region.

Keywords: maximum likelihood estimation, maximum Lq-likelihood estimation, parameter estimation, relative efficiency, salary data

In statistical analysis, accurately estimating distribution parameters plays a key role in understanding and interpreting data. Consequently, selecting the appropriate estimation method is of critical importance, particularly given the diversity of possible distributions. The maximum likelihood estimation (MLE) is a widely used technique for analyzing large-volume data sets. A key feature of this method is that it enables researchers to obtain the most probable values for the model parameters, which best fit the observed data.

In certain instances, researchers may work with data sets that require significant time and effort to collect. Techniques developed for processing large volumes of data may not be suitable for analyzing smaller samples. For instance, when applying the MLE to a small data set, the results may have a large variance, increasing the risk of incorrect conclusions and reducing the reliability of the results.

In this context, it would be more appropriate to use alternative assessment methods. A striking example of such methods is the likelihood method proposed in [1], which is called maximum Lq-likelihood estimation (MLqE). The key feature of this approach is the use of the Lq-function rather than the likelihood function as in MLE. The Lq-function contains a distortion parameter that plays an important role in estimating small and medium amounts of data allowing them to account for outliers.

At the moment, the scientific literature is discussing the research presented in reference [2] regarding the effectiveness of MLqE in analyzing standard gamma distributions. As a result, it was decided, in comparison with other studies, to investigate a two-parameter gamma [3] and gamma inverse distribution [4]. The investigation revealed the MLqE estimation equations and optimal distortion parameters were derived, which allow for the most accurate estimation of gamma and inverse gamma distribution parameters.

The first stage of the study included the creation of models based on samples that were designed in accordance with specified shape and scale parameters, as well as with a specified sample size in the range from 50 to 10 000 specimens. The relative efficiency indicator has been chosen as a comparative measure. If the value of the relative efficiency tends to 1, then MLqE has a greater advantage in terms of parameter estimation. Based on the sample modeling, it has been found that the efficiency of the shapes and scales of the gamma and inverse gamma distributions for small to medium dimensions tends towards 1. This indicates that the MLqE method has an advantage when estimating parameters.

The second phase of the study involved evaluating the gamma and inverse gamma distribution parameters that describe salary data in the Novosibirsk region. Data on vacancies was collected from various job sites and organized into groups based on the All-Russian Classifier of Economic Activities. The interesting thing about the data set under study is that there are a small number of salary values in some positions, and therefore the gamma and inverse gamma distributions based on these samples are difficult to estimate using MLE. As a result of the conducted research, it was found that the value of the relative efficiency indicator tends to 1, therefore MLqE evaluates the parameters better than MLE.

The results indicate that it is important to use alternative methods in the context of a small and medium-sized sample. One such approach is MLqE. The advantage of using this method in evaluation has been demonstrated by using the relative efficiency index of both gamma and gamma inverse distributions.

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AUTOMATION AND COMPUTER ENGINEERING

Research and Development of Software for Comparison of Visual Data with Hashing Methods

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Abstract: The research and development of software for analyzing and comparing visual data using image hashing methods such as A-Hash, D-Hash, P-Hash and W-Hash is examined in this paper.

Keywords: image, comparison, matching, hashing

Currently, working with data without special tools is becoming an increasingly difficult task. This makes developments in the field of indexing and information retrieval especially relevant. This is especially true in the field of visual data processing, where the development of technologies for searching and comparing images based on their content and visual characteristics, such as colors, textures, shapes and contours, is becoming critically important.

There are a number of practical tasks that can no longer be solved without automatic image analysis. These include the search for visual content on the Internet, quality control of printed products, copyright protection and digital forensics. This work is aimed at developing and researching image comparison techniques that will be implemented as software.

The analysis of the subject area shows that the optimal image matching method is selected based on the task at hand. Currently, various image comparison techniques are used, and each has its own strengths and limitations, depending on the required accuracy, processing speed, and ability to withstand distortion. Among the most popular algorithms are the following: image hashing, color histogram analysis, and comparison of coherent color vectors.

Hashing algorithms are most frequently used when searching for images and identifying duplicates. Their principle of operation is to identify special stable image characteristics to create a unique digital fingerprint, i.e. a hash. The main feature of hashing is that identical images form identical hashes,

while different images receive very different hashes [1]. After receiving the hashes, they are compared with a reference using various metrics (for example, the Euclidean distance or the Hamming distance).

The most well-known hashing algorithms are Average Hash (A-Hash), Difference Hash (D-Hash), Perceptual Hash (P-Hash) and Wavelet Hash (W-Hash) [2]. Their main difference is displayed when working with transformed images (changed in brightness, size, contrast, using effects of sharpness, blurring, color correction or rotation).

As part of the work, software was developed for image matching using hashing algorithms. At the first stage, different types of hashes were calculated for the reference image. Further, the image was subjected to copying attacks by software, for example, increasing and decreasing the brightness of the image, adding salt and pepper noise, etc. For the resulting duplicate images, hashes were calculated, which were then compared with reference ones using metrics such as the Hamming distance (Fig. 1), the Levenshtein distance, and the Jaro-Winkler distance.

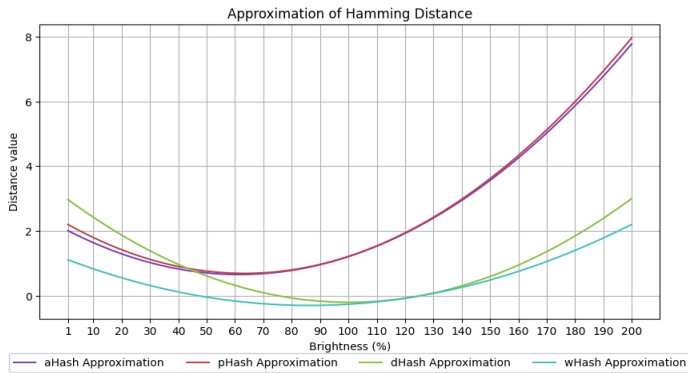


Figure 1 – Approximation of the Hamming distance for different hashes with increasing and decreasing brightness of the reference image

It is worth noting that the Wavelet Hash (W-Hash) has demonstrated high efficiency in protecting against various attacks on images.

The use of modern image matching methods makes it possible to achieve higher accuracy and reliability in the analysis of visual data. This fact is particularly important in the areas where image quality control plays a crucial

role, for example, in the printing industry, where it is extremely important to identify any printing defects in a timely manner.

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Applying Interactive Visualization Techniques for Enhancing User Understanding in Multi-Criteria Evolutionary Algorithms

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Abstract: This paper presents an interactive software tool designed to enhance user understanding of multi-criteria evolutionary algorithms (MOEAs) through advanced visualization techniques. The system focuses on making the internal processes and outcomes of MOEAs more interpretable and accessible to users by enabling dynamic exploration of solution spaces, real-time feedback, and intuitive interaction with the evolving Pareto front. Rather than concentrating on algorithm development, this work emphasizes user-centered design in the context of evolutionary optimization, highlighting how interactive visualization can demystify complex algorithm behavior and support learning, analysis, and decision-making.

Keywords: evolutionary algorithms, multi-objective optimization, Pareto front, interactive visualization, user understanding, decision support

Multi-criteria evolutionary algorithms (MOEAs) are widely used for solving optimization problems involving multiple, often conflicting,

objectives. Among the most well-known algorithms in this class is NSGA-II, which introduced efficient mechanisms for Pareto-based selection and diversity maintenance [1]. However, despite their practical power, the conceptual complexity of MOEAs (particularly the ideas of Pareto dominance, convergence, and diversity) can present a steep learning curve for non-experts [2].

To address this, we propose a visualization-driven approach to make MOEAs more accessible and interpretable. Through interactive visual representations and real-time parameter adjustments, users can gain hands-on experience and a clearer mental model of how solutions evolve over time.

The tool was developed in C# using Windows Forms in the Microsoft Visual Studio environment. Its architecture is modular and designed to support experimentation, learning, and analysis. Core features include:

Live Pareto Front Visualization: Real-time 2D plotting of solution fronts during algorithm execution, illustrating convergence and diversity dynamics.

Interactive Parameter Adjustment: Users can modify evolutionary parameters (e.g., population size, mutation rate) on-the-fly and observe their impact visually.

Trajectory Exploration: Visual tracking of individual solution trajectories across generations to help understand selection and survival patterns.

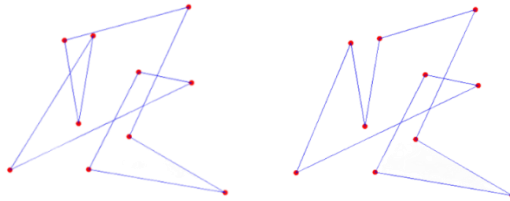


Figure 1 – Example of route improvement visualization after one iteration of the optimization algorithm

Exploratory Analysis Tools: These include metrics such as crowding distance, dominance depth [1], and clustering of solutions, enhancing the interpretability of population structure.

The system supports both educational and research contexts. For learners, it serves as an intuitive introduction to evolutionary concepts through experimentation and visualization. For analysts, it offers a way to diagnose

algorithm behavior, compare performance under different settings, and interpret results in the context of multi-objective trade-offs.

This work demonstrates the value of interactive visualization in fostering better understanding of MOEAs. By shifting focus from algorithm internals to user experience and system feedback, the tool enables deeper engagement with optimization processes. Future improvements will include expanded algorithm support (e.g., MOEA/D, SPEA2 [2]), customizable objective functions, and integration of user preference modeling for interactive decision support.

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The Challenges of Production Management Training Simulators Utilizing

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Abstract: This paper deals with the problem of production management training simulators. The development of simulators can be useful for the process of learning the concept of Theory of Constraints.

Keywords: training simulators, Theory of Constraints (TOC), production management

Nowadays, training simulators are increasingly in demand as they can simulate various situations, allowing users to practice and train their skills in realistic environment. When studying production management, one needs to

understand all types of production environments and all types of production flow, as well as the concept of the Theory of Constraints and the optimization problem of planning. Based on this knowledge, one manages a manufacturing enterprise to utilize resources efficiently.

Since it is costly and difficult to learn to make decisions based on this knowledge in realistic environment, a training simulator, which includes a variety of problems that address a particular production flow and control problem, will make the learning process more visual and give the trainees the opportunity to test different solutions for themselves.

There are only a few production management training simulators in the public domain currently, and they do not simulate all the production processes required.

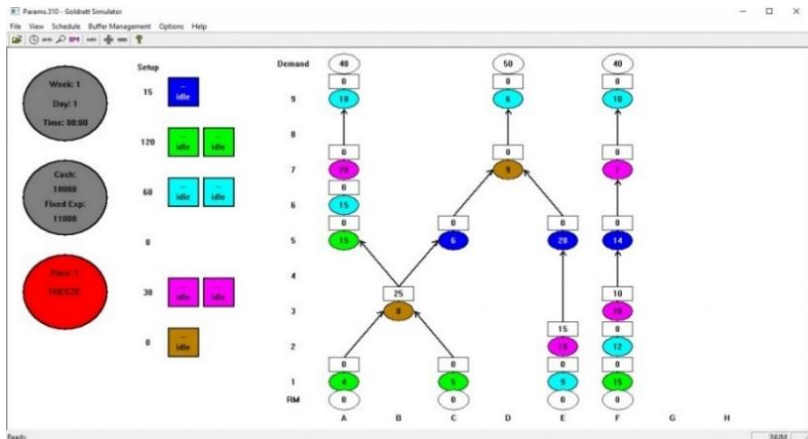


Figure 1 – The G-Sim simulator

An example of such a simulator is the G-Sim simulator created in 1986 by Eliyahu M. Goldratt [1]. This simulator (Fig.1) is designed to build decision-making skills within the concept of the Theory of Constraints in production management. The simulator covers all types of production environments and all types of production flow (V-A-T-I) and is used to teach the concepts of Theory of Constraints and functional management in companies. G-Sim can also be used to teach how to implement TOC solutions for operational processes in service industries [2].

For this reason, the development of a similar simulator can help students in the process of learning the concepts of Theory of Constraints in production management disciplines. It is expected that due to the reusable calculations with necessary comments, as well as visualization of the solution process and its results, the simulator will provide an opportunity to understand and master the method of constraints in solving problems widely used in operational management, in particular, in the scheduling of production processes. It will also allow to ‘repeat’ the reality of the production environment and promptly demonstrate the results of the management decisions taken.

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A Computer Game with a Player – a Neural Network Trained via Reinforcement Learning

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Abstract: A computer game in the «tower defense» genre, in which the player is a neural network trained using the reinforcement method is described in this paper.

Keywords: computer game, neural network, reinforcement learning, machine learning, artificial intelligence

In recent years, there has been an increasing interest in the field of neural network research. Neural networks and artificial intelligence have already significantly changed our daily lives. With advancements in machine

learning, especially deep reinforcement learning, researchers and developers alike are exploring new ways to create intelligent agents capable of mastering complex game environments.

A major boost to the development of deep reinforcement learning was the DeepMind experiment with Atari games. It all started with Vladimir Minkh's paper in 2013, which proposed a new way to train neural networks and trained a neural network based on «raw pixels» from a screen [1].

Games offer a rich and controlled environment for experimenting with AI techniques. Unlike many real-world applications, games have clearly defined rules, feedback mechanisms (e.g., rewards and penalties), and measurable outcomes. As a result, they serve as ideal testbeds for training and evaluating intelligent systems.

The use of reinforcement learning, in particular, has gained significant attention because of its ability to train agents through interaction with the environment without explicit supervision. The agent learns to make decisions by receiving rewards or punishments based on its actions, gradually improving its performance through trial and error. This approach closely mirrors how humans learn in real-world scenarios, making it both powerful and intuitive.

In this context, strategy games such as *Plants vs. Zombies* are especially appealing. They require planning, resource management, and adaptability making them challenging and rewarding environments for training AI. This thesis explores the development of a computer game inspired by *Plants vs. Zombies*, in which the player is not human, but a neural network trained via reinforcement learning. The aim is to investigate how such an AI can learn to make strategic decisions and compete effectively in a dynamic, multi-agent environment.

Based on the comparative study by De La Fuente and Guerra [2], we expect that among the tested reinforcement learning algorithms, Deep Q-Network (DQN) and Proximal Policy Optimization (PPO) will demonstrate greater stability and robustness in our strategy game environment, while Advantage Actor-Critic (A2C) may require more careful tuning of hyper-parameters. DQN is likely to excel in long-term planning and resource management due to its ability to optimize for delayed rewards, whereas PPO's clipped updates may provide more consistent learning in dynamic scenarios. A2C, although more sensitive, could offer faster adaptation in

rapidly changing game conditions. These expectations will inform the evaluation of how effectively each algorithm enables a neural network to learn strategic decision-making in a complex multi-agent environment.

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Semantic Information Retrieval: Mathematical and Software Solutions for Electronic Library System

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Abstract: The study addresses modern approaches to semantic information retrieval in electronic library systems amid the rapid growth of digital text data and the increasing demands for search precision, relevance, and completeness. In the current landscape, most electronic libraries predominantly rely on traditional keyword-based matching techniques, which significantly limit the relevance and semantic depth of retrieved results, especially in the context of scientific and educational materials where terminology may vary or evolve. The present paper focuses on a theoretical analysis of classical statistical methods for text processing, such as TF-IDF, and neural network approaches based on distributed word embeddings (e.g., Word2Vec). In addition, attention is given to more advanced models based on transformer architectures, particularly BERT, which allow for capturing contextual relationships between terms within texts. Preliminary findings emphasize that context-aware models offer notable advantages in enhancing the quality of semantic information retrieval by better reflecting the nuances of language. Future research is planned to involve the fine-tuning of transformer-based language models to the specific features of academic and educational discourse, aiming to contribute to the development of more intelligent, adaptable, and effective semantic search systems

for electronic library environments.

Keywords: natural language processing, semantic text similarity detection, machine learning, deep learning, TF-IDF, Word2Vec, BERT, transformers, text vectorization

Electronic library systems (ELS) are crucial for providing access to educational and scientific resources. However, most existing ELS rely on traditional keyword-based search technologies, which fail to capture semantic relationships between terms, limiting the relevance and completeness of search results. The research explores two key directions for improving semantic information retrieval in ELS: (1) the integration of modern natural language processing (NLP) models capable of understanding context, synonyms, and thematic proximity, and (2) the use of vector-based text representations that encode semantic relationships between language elements.

Both approaches aim to create intelligent, adaptive library systems that better align search results with user needs and the specific characteristics of scientific domains. By enabling search engines to operate not only with isolated keywords but with the meanings and contexts of terms, these methods promise to significantly enhance the effectiveness of information retrieval in electronic libraries.

1. Evolution of Text Vectorization Methods. Traditional approaches to text vectorization in electronic library systems have relied on models like TF-IDF (Term Frequency–Inverse Document Frequency), which assess term significance based on frequency distributions across documents [2]. While effective for basic keyword matching, TF-IDF struggles with capturing synonymy, homonymy, and word order, limiting its performance in semantic retrieval tasks.

The introduction of distributed representations through neural network models, such as Word2Vec, marked a significant advancement. Word2Vec generates dense vector embeddings for words based on their contextual usage, enabling models to recognize semantic proximity even between differently spelled terms. For instance, vectors for "car" and "automobile" appear close in embedding space, reflecting their semantic similarity.

2. Context-Aware Language Models. The most transformative progress in natural language processing has been driven by the development of transformer-based architectures, particularly BERT and its variants [1].

Unlike earlier methods, these models generate bidirectional contextual representations by considering both left and right contexts simultaneously. This capability is critical for interpreting complex, ambiguous phrases and for retrieving information based on meaning rather than surface form.

BERT's contextual embeddings have significantly improved performance in semantic search, text classification, and information extraction tasks, enabling library systems to match documents not only by formal keyword overlap but by underlying semantic relevance [3].

3. Comparative Evaluation. To evaluate model effectiveness, three approaches—TF-IDF, Word2Vec, and BERT—were tested on a curated corpus of 50 educational documents. Key performance metrics were as shown below in Table 1.

Table 1 – Key performance metrics of the approaches tested

Model	Precision@5	Recall@5
TF-IDF	0.55	0.48
Word2Vec	0.69	0.64
BERT	0.82	0.76

Precision@5 measures the proportion of truly relevant documents among the top 5 retrieved results, while Recall@5 captures the proportion of all relevant documents successfully retrieved within the top 5. The results show that transformer-based models deliver a 25–30% improvement in search quality over classical methods, confirming their potential for enhancing electronic library systems.

4. Strengths and Limitations. There are following limitations of the approaches. TF-IDF does not take into account word order and context, does not handle synonyms and homonymy well. Word2Vec requires large corpora for high-quality training; without additional training on specialized topics, it loses accuracy in specific queries. BERT's limits include a high computational cost of inference and the need for resource servers when scaling the search.

Moreover, all neural network-based methods necessitate the indexing of document vector embeddings and the adoption of specialized search infrastructures (e.g., FAISS), complicating their integration into traditional ELS architectures.

5. Future Directions. Modern methods of natural language processing have significant potential to improve the quality of information retrieval in electronic library systems. Using BERT-type models allows not only to take into account the semantic proximity of texts, but also to find relevant documents with incomplete, synonymous and contextual queries.

To further improve the effectiveness, the following is proposed: adaptation of pre-trained models to the specifics of scientific and educational texts using additional training (fine-tuning); integration of lighter DistilBERT-type models to reduce computational costs; development of hybrid systems combining semantic search with metadata (for example, author, publication year) to improve the accuracy of results.

Future research will focus on expanding the test corpus, implementing multilevel search methods (semantic + meta-information), and optimizing performance on big data.

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Investigation of Algorithms and Programs for Numerical Modeling of Seismo-acoustic Wave Fields Emitted by Traffic Flows

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Abstract: Seismic monitoring of transport impact on the environment in conditions of active urban development is an acute issue nowadays. Possible approaches to solving the corresponding problem of obtaining spectral-temporal characteristics of seismic and acoustic vibrations emitted by different types of transport are investigated in current research. Numerical modeling of seismo-acoustic vibrations is considered as one of the main approaches.

Keywords: transport noise, numerical model, spectral-temporal analysis

Currently, the task of seismic monitoring of transport impact on the environment in conditions of active urban development is of great relevance. Passing along the earth's surface, seismic waves can affect the well-being of people in populated area and the settlement structures.

The topic sets out the problem of assessing geo ecological risks for the environment and humans caused by seismo-acoustic wave fields generated by various types of transport vehicles (i.e., "transport noise"). Possible approaches to solving the corresponding problem of obtaining spectral-temporal characteristics of seismic and acoustic vibrations are investigated in current research.

A natural experiment is considered as a basic setting. Transport noise characteristics can be obtained by placing recording equipment, carrying out a set of measures and analyzing collected data sets. A series of recordings of seismic and acoustic responses have been made in the area nearby to railway tracks and a highway. Autonomous recorders Baikal-ASN have been used to capture data from three-component seismic sensors «GS-3» and modified acoustic sensors «PDS-7». A spectral-temporal analysis of time series has been performed to obtain characteristics of transport noise and to identify the predominant frequency corresponding to the main engine operating frequency. One of the results is shown in Figure 1 below.

An alternative method (in conditions of low equipment availability, or when for some reason such measures are difficult to carry out) can be a numerical experiment. The mathematical description of transport noise is considered as the sum of quasi harmonic functions with variable parameters and a broadband noise component reflecting the interaction of the source with the environment during its movement [1]. In the context of the subject area, a number of numerical models describing the propagation of seismic vibrations from various types of transport vehicles, such as a train and a car,

have been identified in earlier studies [2,3].

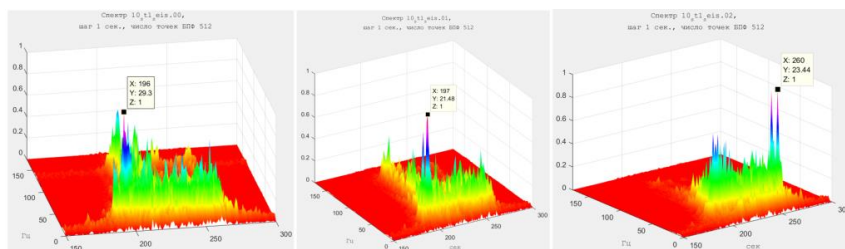


Figure 1 – Spectral-temporal functions with the predominant frequency picking

The results of spectral-temporal analysis of seismograms obtained in a full-scale experiment can be used as a criterion for precision verification of the models. It has been noted that the models considered do not provide a sufficient representation of the transport noise spectral characteristics in urban areas, where the transport routes of cars, trains, trams, airplanes, etc. run close to or intersect with others.

Thus, the next can be hypothesized: "Seismic (or seismo-acoustic) vibrations from different sources of transport noise can be described by a *single* numerical model."

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Emulating Firmware for IoT Security

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Abstract: This paper examines the rapid expansion of the Internet of Things and its accompanying security vulnerabilities, highlighting critical risks from default credentials to firmware weaknesses. It further proposes automated firmware emulation frameworks and integrated testing approaches as effective solutions to strengthen IoT security.

Keywords: firmware, emulation, fuzzing, internet of things

The Internet of Things (IoT) has evolved into a foundational technology. IoT spans wearables, smart homes, industrial systems, and urban infrastructure, with global deployments projected to near 30 billion devices by 2030 [1].

This growth is fueled by plummeting hardware costs, ubiquitous connectivity, and demand for automation. Smart home device shipments alone are expected to hit 1.8 billion by 2025, while industries leverage IoT alongside AI and digital twins for predictive maintenance and efficiency. Agriculture, healthcare, and smart cities further exemplify IoT's transformative potential – enabling precision farming, remote patient monitoring, and data-driven urban management.

According to recent research, the rapid adoption of IoT devices, from smart sensors to connected medical equipment, has introduced severe security risks, with over 50% containing critical vulnerabilities (IBM X-Force). One in three data breaches now involves IoT (Verizon DBIR), exemplified by the Mirai botnet hijacking devices for large-scale DDoS attacks. Healthcare IoT attacks surged by 123% (Statista), while 60% of breaches stem from unpatched firmware (IoT Security Foundation). Default passwords persist in 20% of devices, and industrial IoT attacks rose by 75%,

threatening critical infrastructure (Verizon DBIR). Compromised cameras, smart locks, and even vehicles expose physical security, with breaches costing \$330,000 on average (NIST). Despite these risks, 76% of IoT communications remain unencrypted (Zscaler), leaving corporate networks vulnerable. The convergence of operational disruption, financial loss, and reputational damage underscores the urgent need for robust IoT security measures [2].

For example, the Eleven11bot botnet discovered in 2025 has exploited weak or default credentials along with unpatched firmware in over 86,000 devices such as security cameras and network video recorders, launching massive DDoS attacks and fueling ransomware campaigns in sectors like healthcare and smart cities. Similarly, a critical zero-day flaw in Edimax IP cameras, as reported by CISA, permits remote code execution, thereby allowing attackers to commandeer these devices for unauthorized surveillance and data theft. Moreover, the persistent Raptor Train botnet, active since 2024, has compromised more than 200,000 devices globally by leveraging default SSH and Telnet credentials along with unsecured communication protocols to target vital infrastructure spanning energy grids, transportation systems, and government networks. These examples underscore the escalating threat landscape and the urgent need for robust IoT security measures.

Finding vulnerabilities in firmware presents a host of complex challenges for researchers. Unlike traditional software, firmware operates at a low level, often with limited documentation and visibility, making it difficult to reverse-engineer and analyze. Researchers must contend with different hardware architectures, proprietary code, and the absence of standardized interfaces, all of which obstruct systematic testing. The proprietary nature of many firmware implementations means that even when vulnerabilities are identified, responsible disclosure and prompt patch development are frequently hampered by opaque vendor response processes. These factors, combined with the inherent difficulties in emulating hardware environments for dynamic testing, underscore the urgent need for improved methodologies, industry collaboration, and enhanced security practices throughout the firmware supply chain.

A promising solution lies in the development and adoption of reliable firmware emulation frameworks. These frameworks enable security

researchers to recreate the operational environment of IoT devices in a controlled lab setting, significantly enhancing the accuracy and efficiency of vulnerability testing. By emulating the firmware along with its native hardware interactions, testers can run a variety of automated scanners that identify configuration errors, outdated software components, and other weaknesses without physically accessing the devices.

Moreover, binary fuzzing techniques can be integrated within these emulated environments to inject unexpected or malformed inputs into the firmware. Combining these methods with static and dynamic analysis tools creates a comprehensive testing suite that simulates real-world attacks, allowing researchers to safely explore edge cases and rare conditions that could lead to critical vulnerabilities.

The firmware emulation process can be divided into four main stages, each of which can be largely automated to streamline research efforts and make vulnerability assessments more accessible for bug hunters, red teams, and security specialists [3]. Here's a detailed breakdown.

1. Acquisition. At this stage, the firmware image is obtained from the target device. This can be done through various means such as over-the-air updates, physical extraction from the hardware (using tools like serial interfaces or JTAG), or downloading images provided by vendors. Automation tools can routinely scrape manufacturer sites or repositories, ensuring a steady influx of images without manual intervention.

2. Once acquired, the firmware is often bundled or compressed, containing multiple files and proprietary file systems. The unpacking stage involves decompressing these images and extracting the various components, such as bootloaders, kernels, and application binaries. Automation of this stage proves to be the most difficult as many manufacturers use encryption and proprietary packing methods.

3. Preparation involves setting up the firmware's operational environment by configuring file structures, network settings, and peripheral interfaces that the firmware expects to interact with. This stage adapts the extracted firmware components to an emulated environment, guesses correct kernel if none is provided and maps virtual hardware.

4. The final stage is emulation, where the prepared firmware is executed within a virtualized environment. Platforms like QEMU can be integrated to mimic the hardware, enabling dynamic testing and interaction with the

firmware as if it were running on its native device. Automated bootstrapping and integrated scanner frameworks (including fuzzers and other vulnerability detection tools) can continuously test the running firmware, looking for anomalies or exploitation vectors.

By integrating automation into the emulation process, from acquisition to dynamic testing, security teams can more effectively uncover vulnerabilities and develop robust defenses against emerging IoT threats.

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Automated Audit of Information Security Events in SIEM: An Iterative Approach with Mathematical Formalization

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Abstract: This research presents an automated security event audit system that enhances the comprehensiveness and quality of logging within Security Information and Event Management (SIEM) systems. The system employs the iterative Plan-Do-Check-Act (PDCA) methodology, ensuring continuous improvement of logging processes. A mathematical model describing the evolution of discrepancies in logs over time is presented, allowing for quantitative evaluation of audit effectiveness.

Keywords: Information Security, SIEM, PDCA, security events

The developed software automates the collection, prioritization, and correction of logging gaps using formalized completeness metrics. Experimental results confirm that the iterative improvement cycle significantly reduces data loss and enhances security event coverage, improving the effectiveness of incident investigations.

Effective security event monitoring relies on comprehensive and consistent log collection. However, real-world SIEM systems often face incomplete, missing, or inconsistent logs, resulting in missed incidents, delayed responses, and compliance issues. To address these challenges, we propose an automated auditing system that periodically assesses log completeness, prioritizes missing data, and recommends corrective actions.

The system is built upon the PDCA methodology, systematically and iteratively enhancing logging quality. The automated audit system implements the PDCA cycle as a structured approach to improving log completeness:

1. Plan → Identifying missing logs and classifying event sources
2. Do → Applying corrective actions (e.g., enabling missing logs)
3. Check → Reassessing logging completeness using predefined metrics
4. Act → Adjusting configurations and repeating the cycle

To assess process efficiency, a formal mathematical model is introduced. The primary model variable is the logging error $e(t)$, reflecting discrepancies between actual and expected logs at iteration t . Error evolution is modeled by the equation:

$$e(t+1) = \alpha * e(t) + \gamma \quad (1),$$

where $0 \leq \alpha < 1$, efficiency coefficient indicating the rate at which logging gaps decrease; γ represents external factors influencing log completeness (e.g., adding new servers or changing requirements).

This model quantitatively assesses iterative improvements, illustrating the system's effectiveness in eliminating missing logs. Software implementing this methodology automates security log audits. The primary functions of the system include the following ones:

1. Log collection from various sources (OS logs, audit systems, web servers, databases);
2. Assessing log completeness by using the following metric:

$$Coverage(i,j) = E_{actual}(i,j) / E_{expected}(i,j) \quad (2),$$

where $E(i,j)$ is the number of logs collected, and $E_{expected}(i,j)$ is the anticipated number of events.

3. Prioritizing corrections based on missing log criticality:

$$P(i,j) = W(i,j) * (1 - Coverage(i,j)) \quad (3),$$

where $W(i,j)$ is the criticality weight factor (e.g., OS logs might have higher priority than web logs).

Screenshots of the system interface demonstrate real-time auditing, analyzing log availability, and highlighting problematic areas. The software has been tested in an operational SIEM environment, analyzing log completeness across several servers. Key results indicate significant improvement in logging comprehensiveness, enhancing threat detection and incident investigation.

Future research directions include:

1. Expanding audit metrics, incorporating anomaly detection methods in logs;

2. Integrating AI-based solutions for automated logging parameter tuning;

3. Testing the system in large-scale SIEM environments with diverse infrastructures.

The presented findings show that systematic and iterative audits substantially improve logging completeness, thus aiding threat detection and enhancing information security investigations.

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Sign Language Recognition of Russian Sign Language Using Non-Manual Components

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Abstract: In this paper, the concept of mouthing is considered in the context of sign languages and modern models of visual speech recognition are compared. A solution is also proposed to solve the problem of recognition of mouthing in Russian sign language.

Keywords: non-visual component, Russian sign language, mouthing, visual speech recognition

At the beginning of 2020, according to the All-Russian Society of the Deaf, there were more than 13 million people with hearing impairments in Russia, including over 1 million children [1]. Russian sign language allows people with hearing loss to communicate with each other, and automating its recognition allows to break down the barrier between people with hearing loss and those without such a problem. These facts indicate that the problem remains very relevant.

A non-manual component is an element of a gesture that is not related to a hand movement, such as a head position, mouthing, or a facial expression. In Russian sign language a non-manual component is present in every gesture. Despite the importance of non-manual components, in modern research, their recognition is not given enough attention or they are completely ignored. Meanwhile, the integration of non-manual elements into gesture recognition processes can significantly improve the quality of speech recognition.

The purpose of this article is to propose a solution to the problem of recognizing one of the non-visual components (mouthing) in Russian sign language.

Mouthing is the articulation or parts of it that accompanies the execution of a gesture in sign language. Currently, there are no available models for visual speech recognition in Russian. For this reason, a comparative analysis of models for visual speech recognition in foreign languages is performed.

The following modern models of visual speech recognition in foreign

languages have been found in foreign sources: 1) VSR, 2) TM, and 3) ALR. The models were trained on the Oxford-BBC Lip Reading Sentences 2 (LRS 2) dataset. The dataset consists of video clips of sentences in English from the BBC channel, each sentence is up to 100 characters long [2].

The results of the word error rate of the models were compared. The word error rate is the most common metric used in speech recognition. It is determined by the following formula

$$WER = \frac{S+D+I}{N},$$

where S is the number of substitutions, D is the number of deletions, I is the number of insertions required to convert the predicted sequence to the target sequence, and N is the total number of words in the target sequence. Table 1 shows the results of the models' comparison.

Table 1 – Results of the word error rate of the models

Model name	Word error rate
VSR	29.5
TM	50
ALR	56.29

From this comparison, it can be concluded that the VSR model performs better with visual recognition of a foreign language.

As part of further work to solve the problem of mouthing recognition in Russian sign language, it is necessary to retrain the model for visual speech recognition. For this task, you need a dataset with words in Russian that correspond to gestures. But at the moment, there are no complete data sets in Russian in the public domain.

There are two possible solutions for compiling a dataset:

1) to collect a small amount of data manually and to supply it with generated data;

2) to use the LRS 3 dataset, as it contains a small percentage of data in Russian.

However, it is necessary to understand that this set has not appeared in the public domain yet, and there may not be enough data for full-fledged

training. From this, we can conclude that the first solution is the most appropriate one.

To generate additional data, it is proposed to use various currently existing avatar systems for visualization of Russian sign language. An example of such a system is a system called «Adaptis».

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Application of Python Language to Develop Software Architecture for Acoustic Source Localisation

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Abstract: In this paper, a modular system is developed to calculate the coordinates of an acoustic source taking into account environmental effects. Implementation in Python using numpy, scipy, pandas, matplotlib and plotly provides efficient data processing and optimisation of algorithms.

Keywords: modular approach, python, sound source localisation

The task of localizing acoustic sources is one of the key tasks in a number of modern application domains. Using the Python language to solve such problems offers significant advantages. Python has a large ecosystem of

libraries for numerical calculations and data processing, which greatly simplifies the implementation of complex mathematical algorithms.

Modern sound source localisation systems often use the Time Difference of Arrival (TDOA) method, which allows to determine the source position with high accuracy. In addition, signal filtering algorithms such as digital low-pass and high-pass filters and cross-correlation techniques are widely used to help isolate the useful signal from the noise.

In terms of software implementation, there are many off-the-shelf libraries for signal processing and numerical computations.

The choice of a modular approach and Python as the main platform is due to the ease of integration of heterogeneous components, high prototyping speed, and a rich ecosystem that allows for easy adaptation to changing project requirements.

Each module is responsible for specific tasks. The data acquisition module is responsible for receiving information from various sensors. It can be implemented using *pyserial*, *socket* and *pandas*. The use of *pyserial* is convenient for serial connections, but its use is limited to connection types. *Socket* provides flexibility for network communication, requiring additional protocol customization, and *pandas* is good at processing structured data, although it is less efficient at processing real-time streaming data.

The data preprocessing and filtering module is responsible for cleaning, normalizing and filtering the collected data, removing noise and preparing the information for further analysis. *Numpy* provides high performance for array operations, and *scipy.signal* provides a set of ready-made algorithms for filtering that require a deep understanding of digital signal processing. Using *pandas* is convenient for structured data, but less efficient for high-frequency streaming operations.

The coordinate calculation module solves the problem of determining the source position using the TDOA algorithm, taking into account weather-dependent corrections. *Numpy* provides fast array calculations, while *scipy* offers additional specialized functions for linear algebra and optimization. *Sympy* is convenient for preliminary analysis, although it is not designed for computationally intensive operations.

The results visualization and analysis module provides graphing, error distribution maps, and visual interpretation of calculation results, which allows for a more visual assessment of the system's efficiency. *Matplotlib* is

the standard for visualization, but may seem less advanced without additional customization. *Seaborn* offers a high-level interface for creating graphs, and *plotly* stands out for its interactivity but requires additional resources and deeper learning of syntax.

The integration and API module is designed to integrate the system with external resources and create APIs for remote data access and system management, which ensures extensibility and compatibility with other systems. *Flask* is easy to learn and widely deployed, but may encounter limitations under high load. *FastAPI* demonstrates better performance and support for asynchronous operations, but requires a modern environment and deeper knowledge of Python typing.

As a result of the analysis, it becomes obvious that basic libraries for numerical calculations (*numpy*, *scipy*) are the undisputed choice for the computational modules of the system, while *pandas* is an excellent tool for data preprocessing, despite its limitations for stream processing. For API implementation, *FastAPI* can be favoured if the system requires high performance, or opt for a simpler solution with *Flask* for low load. Visualisation tools complement the system by providing a qualitative presentation of results, allowing to choose between classical static and modern interactive approaches.

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Research of Discretization Methods of Linear Continuous Control Objects Roman Parygin

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Abstract: Three of the most common methods for obtaining discrete models of continuous systems are discussed in the paper: the matrix method, the Z-transform,

and the Tustin transform. The research methodology was carried out using the example of a “DC motor with independent connection” object.

Keywords: DC motor, mathematical model, discretization methods

Almost all physical processes surrounding a person occur on a continuous time scale. To process such data, computing equipment is used, the work with which implies the transformation of signals into a discrete form. This is necessary for the functioning of such systems as radio, navigation systems, optical communication systems, as well as engine control ones.

In this paper, discrete models of the control object "DC motor with independent excitation" are obtained in three ways. The control circuit of the DC motor with independent excitation is shown in Figure 1 below, where FLD – field winding of a motor; DC – DC motor; Conv.1, Conv.2 – controlled converters for power supply of the armature circuit and motor excitation winding; U_1 , U_2 – voltages at the inputs of the controlled converters; R_{n1} , R_{n2} – active resistances of the converters; U , I – voltage and current at the motor armature; ω – angular velocity of rotation of the motor shaft; M – torque developed by the motor; M_c – torque of resistance on the motor shaft, which we will consider as an external disturbance.

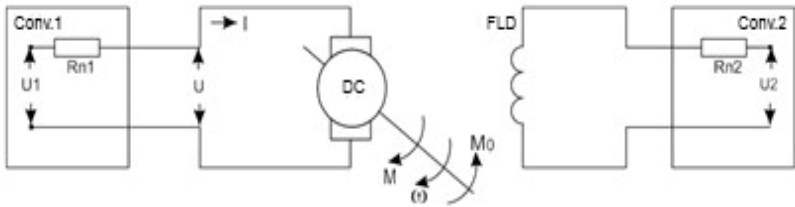


Figure 1 – Control circuit of a DC motor with independent excitation

The mathematical model of the object in the linear approximation [3] has the form:

$$\begin{cases} J \frac{d\omega}{dt} = C\Phi_f I - M_c, \\ L \frac{dI}{dt} = -RI - C\Phi_f \omega + U_1. \end{cases} \quad (1)$$

The system coefficients are calculated based on the passport data. The transfer function of the object is determined taking into account the transfer function of the tachogenerator in the form:

$$W_{\alpha}(p) = W_0(p) \cdot W_{\text{tx}}(p) = \frac{62,5606}{(p^2 + 326,421p + 2426,656)} = \frac{B(p)}{A(p)} \quad (2)$$

Next, we consider transfer functions obtained by transitioning from a continuous model to a discrete one in different ways.

Matrix method:

$$W(z) = \frac{0,0013311508z + 0,000480412}{z^2 - 0,96795436z + 0,03822288} \quad (3)$$

Tustin Transformation:

$$W(z) = \frac{0,00058081z^2 + 0,00116163z + 0,00058081}{z^2 - 0,69767051z - 0,21221207} \quad (4)$$

Z-transform method:

$$W(z) = \frac{0,0013305970603z + 0,000480402}{z^2 - 0,967958941952z + 0,0382271242101} \quad (5)$$

The next step was to compare the transient processes of continuous and discrete objects (Fig. 2).

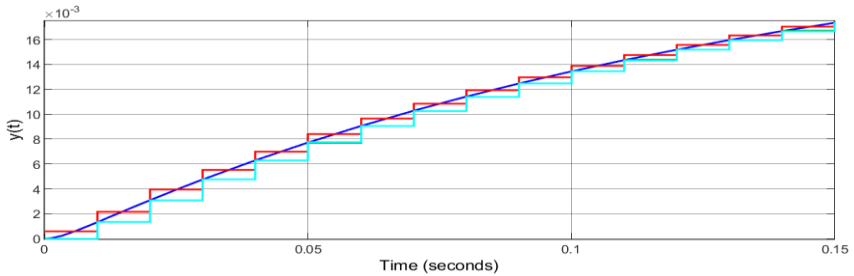


Figure 2 – Graphs of transient processes of a continuous object (blue) and discrete objects obtained by the methods: matrix (green), Z-transform (blue) and Tustin (red)

The transient graphs for the matrix method and the z-transform method coincide. With a small sampling step, and in our case $T = 0.01$ s, these methods show very high accuracy. This leads to the fact that in the figure the

graphs merge into one, and their results converge relative to each other and the continuous model of the object.

The matrix method shows high accuracy, and is also a simple method. The accuracy of the method depends on the number of terms in the expansion series. To achieve a match with the continuous model in this work, 15 terms were needed. An increase in accuracy in this method inevitably leads to an increase in computational loads. Based on this fact, for this object, it is worth giving preference to the Z-transform method, which also allows you to achieve a match with the continuous model, but requires much fewer computing resources.

As a result of the operation of the Tustin transform method, the transient process graph does not coincide with the continuous model at moments equal to the sampling step. Unlike the discrete models obtained by the matrix method and the Z-transform, at the initial moment of time the transient process in the discrete model has a value different from zero $y(0) = 0.0006$. This is due to the fact that the numerator and denominator of the discrete model obtained by the Tustin transform have the same order, which is not observed in the two methods described above. Using the Tustin transform, one can obtain only an approximate discrete model.

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Anomaly Detection Methods in Linux-based Operating Systems with Mandatory Integrity Control Using Machine Learning

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Abstract: An approach to detecting anomalies in Linux-based operating systems with Mandatory Integrity Control (MIC) using machine learning (ML) methods is considered in this research. Unlike signature-based intrusion detection systems (IDS), which rely on static databases of identifiable threats, machine learning allows for the identification of anomalous behavior by analyzing system calls and their parameters. The primary goal of this research is to study and adapt ML algorithms for analyzing system call processes, utilized in Astra Linux, which implements Mandatory Integrity Control.

Keywords: anomaly detection, system calls, machine learning, mandatory integrity control, Astra Linux, security monitoring

Modern information security systems encounter an increasing number of threats aimed at compromising data integrity and confidentiality. In particular, in Linux systems that use Mandatory Integrity Control (MIC), conventional detection methods are often ineffective in identifying novel and sophisticated attacks that exploit previously unknown vulnerabilities. Consequently, anomaly detection methods are gaining relevance, enabling the identification of previously unknown threats by analyzing deviations from normal system behavior.

To address this issue, this study proposes the use of system call tracing analysis with a tool that records call sequences, integrity levels, and process parameters.

This study comprises:

1. Fundamental concepts and principles of Mandatory Integrity Control
2. Examples of MIC implementations in Linux-based operating systems, with a focus on Astra Linux
3. A literature review of various approaches to anomaly detection in system call tracing.

The most effective algorithms for this task have been identified. Approach development for creating an anomaly detection model is based on system call tracing analysis with MIC parameters.

Machine learning methods considered in this study are as follows:

- unsupervised algorithms used for detecting deviations from normal behavior;
- time series methods for analyzing system call sequences;
- classification methods used for training on labeled data and improving anomaly detection accuracy.

Thus, a framework for creating an anomaly detection model based on system call tracing analysis with MIC parameters is proposed. The process consists of the following steps:

1. Data Collection: system calls monitoring, including MIC parameters.
2. Preprocessing: filtering calls, cleaning data, and forming feature space.
3. Feature Engineering: analyzing system call sequences as well as creating feature vectors.
4. Algorithm Selection: testing different ML models.
5. Model Training: hyperparameters fine tuning and preparing the model for practical use.
6. Anomaly Detection: analyzing system calls to detect abnormal activity.
7. Performance Evaluation: analyzing accuracy (Accuracy, F1-score) and model optimizing model.
8. Model Refinement: adjusting features, retraining the model.

Research containerized environments (docker, rootless docker) in Astra Linux are considered in the research as an important aspect of corporate and secure systems. The research explores filtering and optimization opportunities for system call analysis, as well as the impact of MIC parameters on attack detection.

Currently, the study is focused on establishing a theoretical foundation for further research. Prospective work will involve:

- creating system call datasets with MIC parameters;
- developing an anomaly detection model based on system call analysis;
- conducting experiments to evaluate the accuracy of various algorithms and identifying the most effective detection approach;
- adapting the approach for real-time attack detection considering the specific mechanisms of Mandatory Integrity Control.

Thus, this study gives the basis for developing an effective attack detection system, specifically tailored for Linux-based operating systems implementing Mandatory Integrity Control.

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Development of a Segment of the Medical Knowledge Base

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Abstract: The paper considers the solution of the problem of developing a segment of the medical knowledge base, which is designed for use in the outline of the information system “Chronic Heart Failure Registry”. Organization of the knowledge base in the form of tables, rules and algorithms allows to form intermediate results of patient data analysis at different stages of diagnostic decision making.

Keywords: knowledge base, medical knowledge base, represented knowledge

Relevance of development. Nowadays in the environment of medical information systems (MIS) there are more and more solutions for the formation of analytical indicators for making medical decisions. They are based on knowledge, which in turn is stored in MIS knowledge bases [1]. Knowledge in knowledge bases (KB) can be represented using various methods, among which the most popular are tables, rules and diagnostic algorithms.

The paper considers the solution of the problem of developing a segment of a medical knowledge base, which is designed for use in the outline of the information system “Chronic Heart Failure Registry”. The KB should include modules of knowledge storage and representation and an interface

for filling with information. The operability of the knowledge base should be tested on real data.

During the analysis of existing medical knowledge bases (MKBs) it was revealed that there are different types of medical knowledge [2]: tables of reference values; classification and diagnostic algorithms; causal patterns and many others. Among the methods of knowledge representation, the most common in medical information systems are [3]: otology; semantic networks; decision tables and rules; logical and probabilistic models and formalized clinical guidelines.

In the course of solving the task, we analyzed existing developments in this area, designed and developed a knowledge base, developed and implemented the interface of the KB, and performed testing using real data.

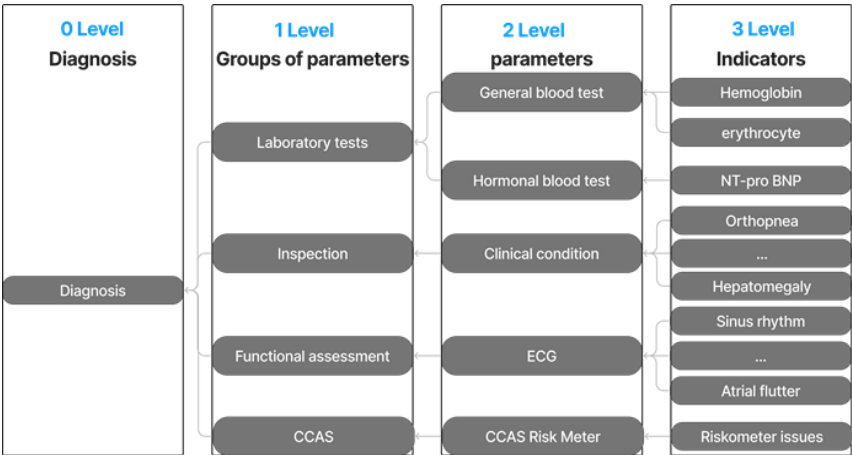


Figure 1 – Structure of the diagnosis in the knowledge base

Also, to verify the correct operation of the knowledge base it was necessary to develop and implement a database with detailed information about the patient on the basis of which a set of diagnostic indices is formed in accordance with the structure of the diagnosis (Fig. 1).

To obtain the final diagnosis, different models of knowledge representation were implemented: tables of reference values and expert evaluations and the product model. Let us consider an example of the

realization of this knowledge in the knowledge base developed using PostgreSQL RDBMS.

The table of reference values stores information with “normal-pathology” boundary values. It is used to evaluate the results of blood tests and the clinical condition assessment scale method, which is implemented using functions and triggers.

Expert evaluation is also presented in the form of a table. It contains the importance value of a certain parameter obtained on the basis of the expert's opinion. This method is used to evaluate clinical condition and ECG.

Productive models represent knowledge in the form of a structure: if (condition), then (actions). Conditions and actions for this method are stored in a table. The method itself is implemented using functions and triggers.

An important stage of the work is to verify the correct operation of the BR. This test was performed on real anonymized patient data. An example of the calculation of diagnostic indices using the developed BR is shown in Figure 2.

123 Пациент	ЛВС Метод	123 Уровень	123 Вес	ЛВС Вывод
2	Гормональный анализ крови	2	1,129	1 Общих анализов гормонов не в норме
2	Общий анализ крови	2	1,059	2 Общих анализов крови не в норме
2	ЭКГ	2	0,56	Обнаружено 4 нарушений ЭКГ
2	Клиническое состояние	2	0,1967	Обнаружено 3 нарушений
2	Функциональная оценка	1	0,56	Есть проблем с Функциональная оценка
2	Лабораторные тесты	1	1,094	Есть проблем с Лабораторные тесты
2	Осмотр	1	0,1967	Нет проблем с осмотром
2	ШОКС	1	0,75	III ФК
2	Диагноз	0	0,6502	Выявлена ХСН

Figure 2 – Result of knowledge base operation

The developed segment of the medical knowledge base was an important step towards systematized storage and processing of information obtained during the development of the information system “Chronic Heart Failure Registry”. Further development of the knowledge base will consist in increasing the methods of knowledge representation and its filling, as well as checking the correctness of work on an increased array of patients.

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Analysis of Advanced Methods for Plant Disease Detection and Phenotyping

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Abstract: This study analyzes advanced methods for plant disease detection and phenotyping, focusing on deep learning, computer vision, and thermal imaging technologies. Two primary approaches are explored: the classification of diseases using RGB images and hybrid models (e.g., CNNs and Vision Transformers), which achieve up to 99% accuracy; and the early diagnosis of biotic/abiotic stresses through thermal imaging paired with machine learning, demonstrating 94–98% accuracy in detecting threats such as drought. The research highlights the complementary strengths of these methods: deep learning excels in visual symptom identification, while thermal imaging enables pre-symptomatic stress detection. However, limitations persist, including the sensitivity of RGB models to environmental variability and the difficulty of differentiating stress types in thermal data. To address these challenges, the study proposes hybrid systems integrating multimodal data and identifies future research priorities, such as synthetic data generation, model interpretability tools, and edge computing for real-time field applications. These advancements hold significant potential for enhancing crop yield and agricultural sustainability.

Keywords: plant disease detection, phenotyping, deep learning, thermal imaging, computer vision, machine learning, precision agriculture, hybrid models, multimodal data fusion

Recent advancements in plant disease detection and phenotyping leverage cutting-edge technologies to address global agricultural challenges. This analysis examines two distinct approaches: (1) deep learning and computer vision techniques for disease classification (as detailed in [1]) and (2) thermal imaging combined with machine learning for early stress diagnosis [2]. Both methodologies aim to enhance precision agriculture by enabling non-invasive, scalable, and real-time monitoring of plant health.

Deep Learning and Computer Vision: [1] highlights the use of Vision Transformers (ViT), convolutional neural networks (CNNs), and ensemble models (e.g., VGG16, ResNet) to classify diseases using RGB images. Key metrics include F1-scores (90–99%), accuracy, and recall, validated on datasets like Kaggle (83,603 images across 55 classes). Hybrid models (e.g., CNN-ViT fusion) achieve 99% accuracy by integrating global and local features.

Thermal Imaging and Machine Learning: [2] emphasizes thermal imaging to detect biotic/abiotic stresses (e.g., drought, fungal infections) by analyzing temperature gradients. The experimental setup uses a Thermal Expert TE-Q1 camera paired with Android devices, achieving 94–98% accuracy in water stress detection. Metrics include Pearson correlations (e.g., $R^2 = 0.91$) and indices like Crop Water Stress Index (CWSI).

Complementary strengths include:

- Deep Learning excels in high-resolution RGB image analysis, identifying visual symptoms (e.g., leaf spots) with robust multi-class classification.
- Thermal Imaging detects pre-symptomatic stress by capturing physiological changes (e.g., altered transpiration), offering early intervention opportunities.

Limitations identified are as follows:

- RGB-based models struggle with environmental variability (lighting, occlusion) and require extensive labeled datasets.
- Thermal methods face challenges in differentiating stress types (e.g., fungal vs. nutrient deficiency) due to overlapping thermal signatures.

Integrating thermal and RGB data could overcome individual limitations. For instance, thermal imaging identifies stress regions, while CNNs/ViTs classify specific diseases within those regions. The second document's

Android-compatible thermal camera (TE-Q1) demonstrates field applicability, aligning with the first document's call for scalable solutions.

However, both approaches require advancements in the following areas:

1. Data Augmentation: Synthetic data generation (e.g., GANs) to address dataset scarcity;
2. Model Interpretability: Techniques like LIME (Local Interpretable Model-agnostic Explanations) to build farmer trust;
3. Edge Computing: Deploying lightweight models on mobile devices for real-time field use.

Both deep learning and thermal imaging offer transformative potential for plant phenotyping. Hybrid systems combining these technologies could achieve superior accuracy and early detection capabilities, directly impacting crop yield and sustainability. Future research should focus on multi-modal data fusion, cost-effective sensor integration, and validation across diverse crops/environments.

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Methodology for Assessing the Level of Trust in Information Exchange Subjects within a Trusted Environment **Alexander Zinakov**

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Abstract: This paper presents a methodology for assessing the level of trust in information exchange subjects within a trusted environment. Key aspects include requirements for personnel and resources, time intervals for assessment, and

algorithms for calculating trust indicators. The proposed approach aims to minimize risks associated with information exchange and ensures continuous monitoring of the assessed objects' status.

Keywords: trusted environment, information exchange, trust assessment, information security, trust metrics

In the context of growing cyber threats and increasing volumes of information exchange, ensuring trust between interacting subjects has become a critical task. The proposed methodology (MALTSIXTE (Methodology for assessing the level of trust in the subject of information exchange in a trusted environment)) is designed to assess the level of trust in information exchange subjects within a trusted environment. Its primary goal is to control risks and prevent threats posed by malicious actors of varying potential.

The methodology includes the following stages:

1. Collection of Trust Evidence

- Dedicated personnel or departments for compiling and analyzing trust evidence.
- Equipping with communication tools and means to monitor the effectiveness of information protection.

2. Time Interval Requirements

- Extended audits (20 working days) and rapid audits (64 hours).

3. Calculation of Trust Indicators

- Use of Harrington's function to automate assessment.
- Linguistic values of trust levels (from zero to high).

The assessment methods applied include the following:

1. Trust Metrics

- Cover segments such as risk management, threat management, information security, protection tools, etc.
- Example: For risk management systems, the completeness of coverage, quality of risk processing, and reassessment are evaluated.

2. Calculation Formulas

- The overall trust level is calculated as the geometric mean of trust factors (Formula 1).
- Partial desirability indicators (metrics) are normalized to fit the range [0; 7].

$$D = \sqrt[i+1]{D_{12} * D_{22} * ... * D_{i2} * W_3}, \quad (1)$$

The proposed methodology enables:

- Continuous monitoring of trust levels;
- Minimization of risks in information exchange;
- Adaptation to changes in infrastructure and regulatory requirements.

The MOUDSIODS methodology represents a comprehensive approach to assessing trust in a trusted environment. Further research may focus on optimizing time intervals and expanding the list of metrics for more accurate assessment.

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BUSINESS AND ECONOMICS

Modern Trends in Freight Traffic Development in the Russian Federation

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Abstract: This research is devoted to identifying the impact of freight transportation on the economy of the Russian Federation and determining ways to improve the transport infrastructure. The study offers a comparative analysis of various types of freight transport and discusses current trends affecting logistics in Russia. The novelty lies in the integrated analysis of historical, technological, and economic factors as well as the practical implications for improving transportation efficiency. The research combines theoretical review with practical data, resulting in a comprehensive approach to understanding the current state and future of freight logistics in Russia.

Keywords: freight transportation, logistics, transport infrastructure, blockchain technologies, digitalization, logistics costs

Freight transportation is a vital component of Russia's economic system. It ensures the steady movement of goods across vast distances, supports domestic production and international trade, and directly influences the country's economic stability.

The aim of this study is to examine the modern state of freight transport in the Russian Federation, to identify its influence on the national economy, and to determine effective ways to enhance existing infrastructure. The object of the research includes the analysis of current freight volumes by transport mode, historical development, and global trends shaping logistics solutions today.

This work is distinguished by its combination of historical and modern data, allowing for a full understanding of how Russia's freight transportation network evolved and where it is heading.

The research covers the early stages of truck development, beginning with Gottlieb Daimler's invention in 1896, to the first Russian truck AMO-F-15 in 1924, and the mass production at the Kama Automobile Plant (KamAZ) starting in the 1970s. This historical background illustrates the strong

foundation of industrial transport capacity in Russia, which underpins current logistics performance [2].

In conducting this research, both theoretical and practical methods were employed. The theoretical section focuses on literature review and trend analysis, including geopolitical influences and digital transformation in logistics. The practical part is based on statistical comparison of different freight transportation modes in Russia in 2024. Road transport leads with 7 billion tons due to its flexibility and widespread accessibility. Railway transport, moving 1.19 billion tons, remains essential for long-distance logistics, especially in resource-heavy regions [1]. Pipeline transport, responsible for 1 billion tons, shows stability and continues to serve as the backbone of oil and gas logistics. Meanwhile, water transport is facing a decline (139.7 million tons), primarily because of infrastructure limitations. Air freight transportation, though minimal in volume (0.5 million tons), maintains significance for high-value and urgent cargo.

In terms of modern trends, the research identifies four major forces shaping the future of Russian freight transportation. The first is digitalization and automation, where AI and blockchain technologies help optimize routing, reduce delivery times, and minimize logistics costs. The second trend is a strong focus on environmental sustainability. Electric and hybrid vehicles are gaining popularity, and logistics companies are integrating renewable energy into their operations. Thirdly, infrastructure development remains a priority. The modernization of roads, railways, and ports is critical to handle increased cargo flows and improve regional connectivity. Lastly, geopolitical factors such as sanctions and the restructuring of international trade routes are encouraging Russian companies to adopt more resilient and adaptive logistics strategies [3].

This study not only documents current conditions but also offers new insights into how freight transport systems in Russia are evolving. Unlike previous studies, which often analyze one transport mode or a single trend in isolation, this research presents a comprehensive picture that includes technological innovation, historical development, environmental responsibility, and economic challenges. Its novelty is in the holistic approach and the integration of diverse yet interconnected factors.

The results of this work can be applied by government agencies, logistics providers, and infrastructure developers. By better understanding freight

trends and transport behavior, stakeholders can make informed decisions that reduce delivery costs, enhance efficiency, and support sustainable development. The study contributes to academic discourse by providing data-based conclusions and comparing national logistics trends to global practices. It also offers practical recommendations relevant to transport planners and policymakers.

In conclusion, freight transportation in Russia is undergoing dynamic changes. The sector is adapting to digitalization, environmental demands, and global uncertainty, all while maintaining its traditional strengths in long-distance and large-volume logistics. This research highlights both the achievements and the ongoing challenges within the freight system, offering a roadmap for further innovation and improvement.

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Economic Development in Resource Extracting Regions

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Abstract: This study investigates the specifics of economic development in resource-extracting regions, focusing on the Novosibirsk region and its efforts to diversify its economy. It analyzes the challenges posed by the "resource curse". The paper

examines specific policies and strategies aimed at fostering innovation and entrepreneurship beyond resource extraction. The findings provide insights into the complexities of managing resource wealth and fostering a diversified economy.

Keywords: resource-extracting regions, resource potential, economic development, diversification of the economy

The object of the study is economic processes associated with the extraction and processing of minerals in the Novosibirsk region.

Critical to the national economy, resource-extracting regions are defined by a dominance of enterprises exploiting natural resources. Economic theory and practice offer various approaches to classifying these regions, based on different criteria that highlight their unique features [1]. See Table 1.

Table 1 – Classification of resource-extracting regions by main features

<i>Classification feature</i>	<i>Description</i>	<i>Examples of regions</i>
<i>Degree of dependence on resource extraction</i>	Regions whose economies depend on mining	Kemerovo region, Khanty-Mansiysk autonomous okrug
<i>Economic structure</i>	Raw material regions where mining is predominant	Irkutsk region, Republic of Sakha (Yakutia)
<i>Ecological approach (ecoregions)</i>	Regions with a homogeneous biotic community where resource extraction impacts the ecosystem	Komi Republic, Chukotka autonomous okrug
<i>Diversification of the economy</i>	Regions with attempts at diversification, where there is a transition from raw materials to multi-sector development	Magadan region, Amur region

Resource regions depend heavily on natural resource extraction, making them key to national economies yet vulnerable to economic and environmental challenges. A single-industry focus limits diversification, while reliance on commodity prices creates sensitivity to market swings, illustrated by Kemerovo. Environmental impacts include water pollution, land degradation, and ecosystem destruction [2].

Lack of diversity causes instability in resource regions, requiring sustainable innovation. Strategies should promote high-tech, improve living, and support young people. Moving beyond unstable resource models demands diversification. Prioritizing technology, agriculture, and infrastructure increases competitiveness. Ultimately, economic, social, and environmental balance ensures prosperity.

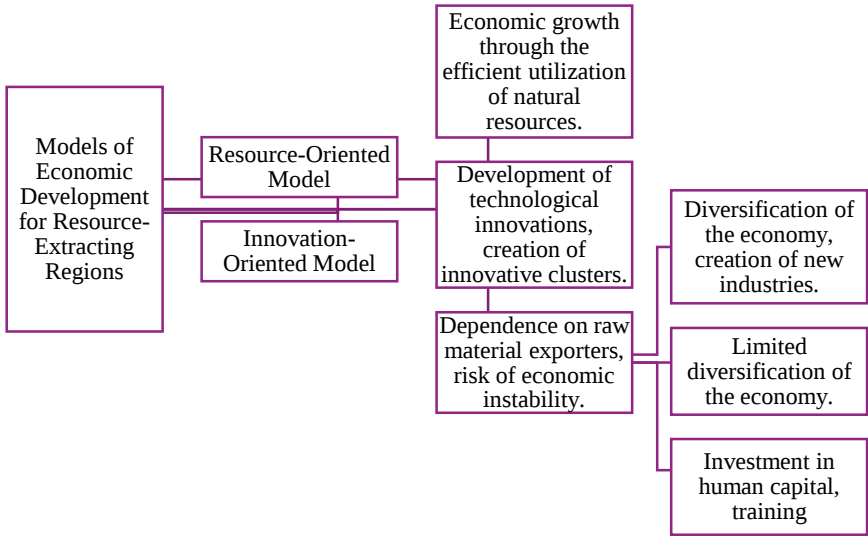


Figure 1 – Models and strategies for economic development in resource-extracting regions

Novosibirsk Region, a key agricultural and industrial center in southwestern Siberia, possesses diverse resources like hydrocarbons, coal, and peat for energy and farming. Although gold and bauxite exist, their future potential lies in economic diversification. Table 2 below provides data

on the extraction of the main minerals in the Novosibirsk region for 2024, which illustrates the current production volumes for the main resource categories.

As Table 2 shows, peat accounts for over 60% of mineral extraction, with oil and gas also dominating Novosibirsk's hydrocarbon-based economy. These data underscore the need to develop industries processing hydrocarbons and peat, as well as for more efficient resource utilization [3].

Table 2 – Extraction of the main minerals in the Novosibirsk region (2024)

Type of mineral	Production (thousand tons)
Oil	1,000
Gas (million m ³)	800
Coal	800
Peat	7,000

Novosibirsk Region's economy is significantly shaped by its geography and diverse natural resources, but realizing its potential requires an integrated approach to resource use, conservation, and development of alternative industries to overcome challenges like limited reserves.

Novosibirsk faces challenges like limited diversification, weak technology, and social inequality. Sustainable growth requires diversifying into high-tech sectors, modernizing infrastructure, and embracing green technologies. Improving social services and integrating science with business are vital for building a sustainable, innovative regional economy [4].

Novosibirsk, despite its resources, faces diversification, infrastructure, and environmental challenges. Future growth hinges on modernization, high-tech industries, and integrating science with business for a sustainable economy and better quality of life.

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MECHANICAL ENGINEERING

Synthesis of Strengthening Phases in the Process of Formation of Composite Matrix Coatings by Electron Beam Surfacing

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Abstract: The study involved a series of surfacing experiments aimed at the formation of titanium diboride and intermetallic compounds at varying concentrations of alloying elements in the Al-Ti-B system. The optimization of process parameters revealed that the most favorable conditions for minimizing the remelting of the modified layer with the base metal are a surfacing current of 18 mA and a boron content of 6% in the Al-Ti-B system.

Keywords: non-vacuum electron beam cladding, carbides, borides, intermetallics, microstructure

Enhancing the efficiency of modern mechanical engineering requires continuous improvement of materials and technologies used in the design of advanced products. Promising approaches for manufacturing such structures may involve the use of austenitic stainless steels combined with modified coatings. Non-vacuum electron beam surfacing enables the production of composite materials consisting of a base metal and a modified strengthening layer of varying thickness, which can reach several millimeters.

Currently, alloying systems such as Al-Ti-B are typically introduced into non-ferrous metals to refine grain structure and enhance mechanical properties. After casting, metastable phases such as TiAl, TiB, and TiB₂ may form in the ingot structure, while subsequent annealing reveals the presence of two equilibrium phases, TiAl and TiB₂. No stable ternary phases form in the Al-Ti-B system [1–2].

The objective of this work is to ensure a combination of functional properties in the formation of "base metal – modified layer" systems with reinforcing particles synthesized during non-vacuum electron beam surfacing of modifying powder compositions.

To achieve this goal, the following tasks were addressed:

1. Optimization of surfacing parameters on austenitic stainless steel workpieces using non-vacuum electron beam surfacing of Ti–Al–B powder mixtures.

2. Evaluation of the influence of non-vacuum electron beam surfacing parameters and deposited mixture composition on the structure and properties of modified layers.

3. Assessment of the phase composition and mechanical properties of "base metal – modified layer" composites.

To produce a high-strength modified layer, samples of austenitic steel AISI 321 were processed via surfacing with powder mixtures using a relativistic electron beam exposed to an air atmosphere. Powder blends of amorphous boron, titanium, and aluminum in varying ratios (Al-Ti-B0, Al-Ti-B2, Al-Ti-B4, Al-Ti-B6, Al-Ti-B8) were deposited using an ELV-6 electron accelerator (Budker Institute of Nuclear Physics, SB RAS).

For microstructural analysis, samples were sectioned, mounted in polymer resin, and subjected to grinding, polishing, and etching with a concentrated acid mixture ($\text{HNO}_3\text{:HCl} = 1\text{:}3$). Metallographic studies were conducted using an optical microscope.

Structural analysis revealed that increasing the boron content in the surfacing layer significantly reduces grain size heterogeneity and refines the grain structure (See Figure 1).

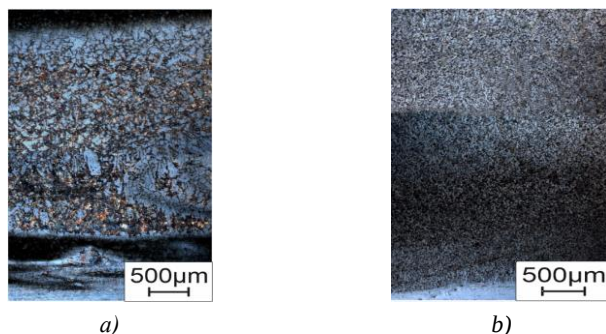


Figure 1 – Microstructure of deposited layers: a) Al-Ti-B0; b) Al-Ti-B8

Mechanical properties were evaluated by Vickers microhardness testing. The average microhardness values of the modified layers ranged from 350

to 700 HV, compared to 200 HV for the base austenitic steel. The highest microhardness (700 HV) was achieved in composition 24 with 6% boron.

X-ray phase analysis of the modified layers confirmed the presence of α -Fe, TiC, and $\text{Ti}_x\text{Fe}_y\text{Al}_z$ phases.

The solid-solution strengthening mechanism can be achieved through non-vacuum electron beam surfacing. This method enables phase synthesis and effective microstructure modification.

The studies were performed on the equipment of the Central Collective Use Center "Structure, mechanical and physical properties of materials" (agreement with the Ministry of Education and Science No. 13.TsKP.21.0034, 075-15-2021-698).

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The Influence of Initial Roughness on the Quality of the Surface of Parts Made of AMg6 Aluminum Alloy after Ultrasonic Surface Plastic Deformation

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Abstract: This article examines the influence of initial surface roughness and the number of passes in ultrasonic surface plastic deformation (USPD) on the AMg6 aluminum alloy. It has been established that roughness and microhardness stabilize after 1–2 passes, with no further improvement.

Keywords: ultrasonic hardening, aluminum alloys, surface plastic deformation, surface quality

Ultrasonic surface plastic deformation (USPD) can improve the quality of the surface layer alongside traditional finishing methods [1]. The oscillation of the indenter alters its interaction with the sample surface, positively affecting the treated surface quality. This method enhances wear resistance, contact strength, and fatigue resistance [2].

This study investigates the effect of USPD on AMg6 aluminum alloy samples with different initial surface roughness values ($R_a = 0.44\text{--}3.00\text{ }\mu\text{m}$). The ultrasonic vibrations were introduced tangentially to the treated surface. The number of passes was varied under fixed processing conditions. The processing was carried out using a spherical indenter made of polycrystalline synthetic diamond. The radius of the working part of the tool was 3.5 mm. After USPD treatment, changes in roughness parameters and microhardness were analyzed depending on the initial surface roughness and the number of passes.

The study confirmed that USPD significantly reduces roughness and increases the microhardness of AMg6 alloy samples, improving their wear resistance and fatigue strength. The method's effectiveness depends on the initial roughness: the higher the initial roughness, the greater the smoothing effect after processing.

The analysis of the surface microgeometry after processing indicates that the reduction of large irregularities from the initial microgeometry formed by turning becomes noticeable after the first pass. Additionally, after the first pass, the characteristic striped structure of turning is replaced by a cellular structure. An increase in the number of passes does not lead to significant changes in surface morphology. Thus, it can be concluded that visually significant alterations in the microgeometric state occur after the first pass and remain unchanged with subsequent passes.

The optimal number of passes to achieve a balance between high microhardness and low roughness is 1–2. Additional passes do not provide significant improvements and, in some cases, may negatively affect surface quality. Instead of multiple passes, adjusting processing parameters based on the initial surface condition is a more effective approach.

These findings can be applied to the development of aluminum alloy hardening methods, the selection of optimal processing parameters, and strategies for preliminary operations to enhance product performance

characteristics. The results obtained in the study can also be applied to improve the USPD technology, ensuring an increase in surface layer quality and processing efficiency, as well as enhancing economic effectiveness.

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The Problem of Space Debris and Its Solutions

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With the development of the space industry, humanity has encountered a serious problem - the accumulation of space debris in low Earth orbit. Every launch of satellites, crewed spacecraft, and interplanetary missions leaves behind fragments of rockets, defunct satellites, and structural components. These objects, with a total mass exceeding 8,000 tons, pose a significant threat to operational spacecraft, the International Space Station, and future lunar and Martian exploration missions.

This article addresses the key aspects of the issue: documented examples of destructive collisions (such as the Iridium-33 and Kosmos-2251 incident), the risk of the Kessler effect, and the importance of continuous orbit monitoring. The author emphasizes the need for advanced observation

technologies – including radars, optical telescopes, and machine learning algorithms – to predict and prevent potential disasters.

Several main strategies are proposed to mitigate the problem: controlled deorbiting of defunct satellites, orbital maneuvering of active spacecraft, and active debris removal using specialized satellites. The article also explores innovative recycling technologies, such as repurposing old spacecraft components into new orbital stations, extracting valuable materials, using 3D printing in space, and generating energy from space debris. Promising future developments include biodegradable satellites, plasma engines, and electromagnetic traps for metallic debris [1].

The article highlights the importance of international collaboration, the establishment of global operational standards, and the possible introduction of an “orbital pollution tax.” Only a comprehensive approach – combining technological, legal, and organizational efforts – can ensure the sustainable and safe development of future space activities [2].

The issue of space debris represents one of the most serious threats to the sustainable development of the space industry. The accumulation of orbital fragments has already led to several dangerous incidents and, if not addressed, may trigger the Kessler effect - a cascade of collisions in space that could render certain orbits unusable. Solving this problem requires a multifaceted approach: implementing active debris removal technologies, developing recycling systems in orbit, enhancing monitoring capabilities, and establishing international legal frameworks that support collaboration.

Only by uniting the efforts of governments, private companies, and the scientific community can we ensure the safety of current and future space missions, preserve near-Earth space as a functional environment, and transition into an era of responsible and sustainable space exploration.

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Magnetic Pulse Welding of Aluminum and Steel

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Abstract: The article discusses a method for obtaining an all-in-one welded joint of flat metal blanks made of aluminum and steel using the magnetic pulse welding method.

Keywords: magnetic pulse welding, welding of dissimilar metals, properties of the welded joint

Magnetic pulse welding is a promising technology in the production of products from several types of metals. This method allows you to combine metals with different mechanical, physical and chemical properties, such as, for example, aluminum and steel. Aluminum-steel composite materials are widely used in engineering due to the ideal combination of their weight efficiency and high mechanical properties.

The physics of the magnetic pulse welding process is based on electrodynamic interaction. Namely, the excitation of eddy (induction) currents in a conductive material, which then interact with a permanent magnetic field. (See Figure 1).

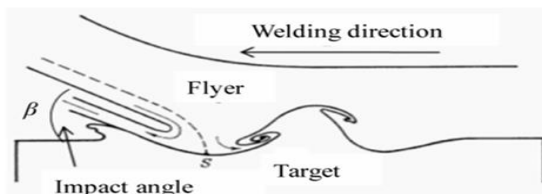


Figure 1 – The transition state of the interface of the welded joint during high-speed impact welding

A necessary condition for welding by this method is collision at an angle with a minimum velocity, which ensures the hydrodynamic fluidity of the material at impact pressure and thereby leads to the formation of mixing waves and bonding [1].

The units of the installation for magnetic pulse welding (Fig. 2) are a high-voltage transformer and a rectifier (1), a pulse current generator consisting of capacitor banks (2) and a spark gap (switch) (3), an inductor (4). A pair of parts (flayer (5) and target (6)) are placed in the working area of the inductor, and a capacitor bank is switched (discharged) onto it [2]. When the capacitor banks are discharged, a current pulse forms an electromagnetic field in the surrounding space, which induces an eddy current in the metal layer of the workpiece. The interaction of two counter-directed currents sets in motion the thrown part, which moves at high speed until it collides with a stationary part, ensuring their welding.

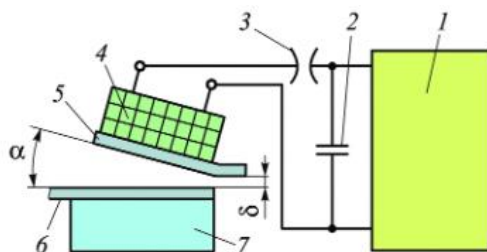


Figure 2 – Installation for magnetic pulse welding

At the moment, there are two main directions: magnetic pulse welding of tubular parts and plate welding. The first area has been studied quite well and is widely used in production. The second one is relatively recent, so research is actively underway to solve a number of pressing problems.

In this paper, we consider a welded joint obtained by magnetic pulse welding of dissimilar flat metal blanks made of A5 aluminum alloy (high purity aluminum) and 20 grade low carbon steel.

An installation created at the Lavrentiev Institute of Hydrodynamics of the Siberian Branch of the Russian Academy of Sciences was used for the experiment. The welding parameters were determined based on the thickness

of the cast plate. The speed and distance traveled of the plate were measured based on the dependence of current on time.

The structure of the obtained sample was studied using optical and scanning electron microscopy methods, and its Vickers hardness was measured.



Figure 3 – The boundary of the welded joint

The boundary between the materials is mostly flat (Fig. 3), and the wave formation process is unstable. Microstructural analysis confirmed that the joint area corresponds to the features characteristic of this welding method.

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The Use of Plastic Deformation to Reduce the Height of Irregularities

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Abstract: For the widespread introduction of titanium alloys into production, it is necessary to develop data on the influence of modes, materials and lubricants on

surface characteristics. This work is devoted to the reduction of surface roughness due to the selection of indenter material and lubricating medium during ultrasonic surface plastic deformation.

Keywords: titanium, deformation, roughness, tool materials, lubricating medium

Titanium alloys are increasingly used every year in the manufacture of products for the aviation and medical industries, rocket engineering and other areas where high strength, resistance to high temperatures and lightness of the material are required. Titanium alloys have such properties [1].

Despite the many advantages of titanium alloys, properties such as low thermal conductivity, affinity with a large number of tool materials, and high hardness lead to processing problems. To overcome these difficulties, the tool material and lubricants should be carefully selected. Unfortunately, this issue is currently not covered in the literature for plastic deformation [2], but it is slightly touched upon for cutting processing. In this regard, this work is devoted to the urgent issue of determining the influence of the lubricating medium and tool material on the surface parameters of the part during processing by ultrasonic surface plastic deformation (USPD).

Prior to the experiments, the samples were turned on a lathe in constant modes to obtain the same initial conditions. USPD processing was carried out on a lathe equipped with a special device. The samples are made of cylindrical shape with a diameter of 60 mm and a length of 120 mm from VT3-1 alloy. The working part of the indenters is made from the following materials: synthetic polycrystalline diamond (ASPK), and hard alloy VK8. The lubricants used included Syncro hypoid oil, Neste lithium grease, and graphite grease Oilright. The roughness was measured using a MarSurf PS10 Set profilograph.

As a result of the study, it was established that when treated with ultrasonic surface plastic deformation with a VK8 hard alloy indenter, a decrease in the height roughness parameters can be achieved by using a liquid lubricating medium, the role of which was played by Syncro hypoid oil in these experiments. The application of greases leads to an increase in the height of the irregularities after processing.

When analyzing the data obtained, it was also established that the use of greases (graphite and lithium) leads to a decrease in the height of profile

irregularities when using synthetic polycrystalline diamond as a tool material. Oil treatment results in increased roughness.

The experiments have shown that the surface parameters during ultrasonic surface plastic deformation are influenced by the indenter material and the lubricating medium. When processing with a diamond tool, it is possible to achieve a reduction in the height parameters of roughness by applying greases. If a hard alloy is used as the indenter material, then the height of the profile irregularities can be reduced by using an oil-based liquid lubricant, Syncro hypoid oil. It can be seen from the results obtained that the products in question have the opposite effect when processed with diamond and hard alloy. The complex nature of the pattern of the obtained values indicates the need for additional and more detailed research in this area.

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PHYSICAL ENGINEERING

Investigation of the Characteristics of a Radio-frequency Plasma Generator of a Stationary Negative Ion Source for a Tandem Accelerator

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Abstract: This article examines such characteristics of a radio-frequency plasma generator as the ion current density depending on the generator power and pressure in the chamber. Thermal loads on the Faraday protective screen were measured using a thermal imager, and the power carried away by water cooling was calculated.

Key words: RF driver, grid probe, ion current density, thermal loads

An accelerating source of epithermal neutrons for boron-neutron-capture therapy based on a 2 MeV vacuum-insulated tandem accelerator is in operation at the BINP SB RAS [1]. The existing injector on the tandem accelerator allows to produce a beam of negative hydrogen ions with a current up to 15 mA [2].

A new stationary source of negative hydrogen ions based on radio-frequency induction discharge is being developed for additional requirements of increased reliability, fail-safe operation and easy maintenance of the ion source in clinic conditions. The new injector will utilize a bending magnet and acceleration tube arrangement, which is designed to pre-accelerate the ion beam to 120 kV to facilitate its transport through the tandem electrostatic entrance lens.

The radio-frequency plasma generator is one of the main elements of the negative hydrogen ion source. Plasma is ignited in the cylindrical chamber of the driver by means of induction RF discharge at hydrogen induction and pulsed spark discharge; a slotted Faraday molybdenum screen is installed inside the driver to protect the driver ceramic walls from erosion by plasma. Experimental bench work was carried out to investigate the characteristics. The present work describes the development of a new stationary negative ion source with a radio-frequency plasma generator for clinical applications. The results of the study of its characteristics on the experimental bench are described: probe measurements of the plasma and thermal modes of the main components of the RF driver at different RF power and hydrogen pressure.

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Development of a Luminescent Beam Monitor for a High Power Synchrotron Radiation Source

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Abstract: The luminescent beam position monitor with a diamond screen allows to monitor the position, intensity and shape of the synchrotron beam. Positioning the luminescent screen perpendicular to the incident radiation reduces absorption and heating. The use of a mirror reduces image distortion and corrects perspective distortion. The developed LBM design has a high resolution and allows to monitor the parameters of synchrotron radiation of high power.

Keywords: synchrotron radiation, beam position monitor, luminescent beam monitor, CVD (physical vapour deposition)

Synchrotron radiation (SR) has been very actively used by scientists in almost all fields of science for the last 50 years. The high resolution and non- destructive effects of techniques that use synchrotron radiation produce amazing results. Certain characteristics of SR are required to perform experiments. For this purpose, frontends—areas of experimental stations with insertion devices and necessary equipment—are designed. Beam position monitors (BPM) are important parts of frontends. BPMs are used to determine the position, shape and energy of the beam. [1]

However, the increased energy of photons generated by the insertion device makes it difficult to monitor radiation parameters, especially non-monochromatised radiation. The use of scanners ‘probing’ the radiation beam leads to attenuation of intensity and overlapping of a part of radiation;

pin-diode scanners are unable to detect too high-energy photons, and ionisation chambers, despite high efficiency of detection and visualisation of the beam, require maintenance of a certain atmosphere.

For efficient SR registration in a wide range of energies with the possibility of determining the geometrical dimensions, intensity and visualisation of the beam, the design of a luminescent beam monitor (LBM) with diamond as a luminescent screen was developed (Fig. 1). The LBM allows the position and intensity of the SR beam to be determined with high accuracy while filtering out the low-frequency portion of the radiation.

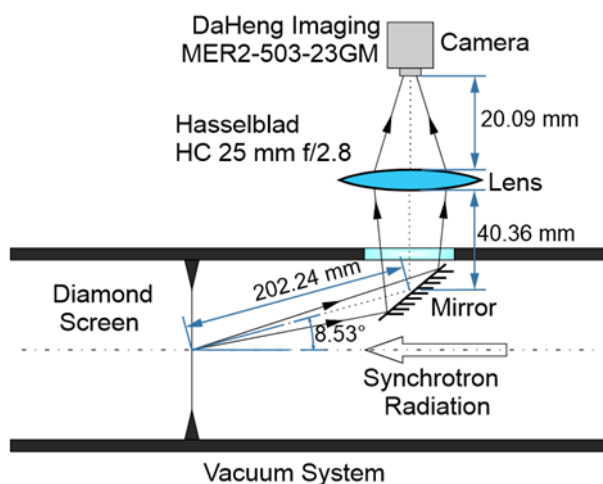
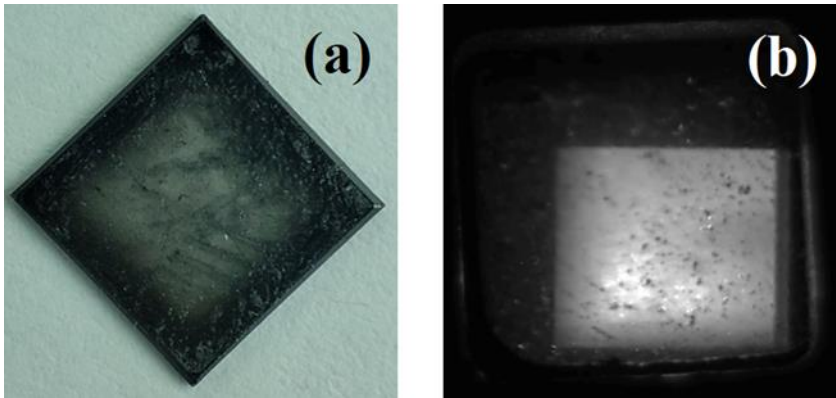


Figure 1 – The LBM optical design schematic representation

The aim of this study is to develop an LBM with a diamond luminescent screen capable of detecting photons in a wide energy range at high thermal loading. Diamond was chosen as the material for the luminescent screen because of its high radiation resistance, high luminescence efficiency and low coefficient of thermal expansion. Positioning the screen perpendicular to the incident SR flux (Fig. 1) reduces the thickness of the material interacting with the radiation. The use of mirror reduces perspective distortion, distortion in the image plane and provides a symmetrical along

the y-axis curvature of the light field. The use of a compact and energy-efficient machine vision video camera allows the centroid and full width at half maximum (FWHM) of the radiation flux to be determined at high speed and at high resolution.

Conducting the experiment at the SR source allowed us to determine the best method of diamond synthesis for the luminescent screen (Fig. 2). Additional image post-processing allows to correct the inhomogeneity of diamond luminescence.



*Figure 2 – (a) Polycrystalline CVD diamond doped with NaGdF₄:Eu;
(b) luminescence image of the diamond screen*

This development has found that generally the resolution of the LMP exceeds the resolution and pixel size of the video camera used. The absolute error in beam centroid determination was less than 1.5 μm . At the same time, the system has a relatively low distortion of 2.5% and small dimensions of the device, which easily allows to build it into the frontends of experimental stations. The use of new composites in CVD (physical vapour deposition) diamond growth improves the signal-to-noise ratio and increases the luminescence efficiency of the diamond screen. [2] The developed LMP design can also be used in less heat-loaded areas of the experimental station, for example, in the optical hatchways of the stations. Further studies of the applicability of metallic glasses, silicon carbide or

aluminum plates with sprayed luminophores as materials for screens represent a promising direction in improving and reducing the cost of the design of the developed device.

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Application Prospects and Unique Characteristics of Carbon Composite Reinforcement

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Abstract: The construction industry is constantly evolving. One of the promising areas of construction development is design and engineering. Composite reinforcement is considered as a relevant topic for this field. For implementation in the construction industry, there is a need to systematize, normalize, update data and additional research into the properties and dependencies of physico-mechanical characteristics of carbon fiber-based composite materials. The research presented in this article is aimed at analyzing experimental data obtained by specialists of the KTB group of companies to determine the possibility of manufacturing carbon-composite reinforcement with a modulus of elasticity exceeding the elasticity

modulus of steel reinforcement. An analysis of the prospects for the use of carbon composite fittings in various fields of construction will also be carried out.

Keywords: composite reinforcement, carbon composite reinforcement, building materials, building structures, reinforced concrete structures, reinforcement with composite reinforcement, modulus of elasticity, strength, electrical conductivity

The previously developed technologies of high-strength, high-modulus carbon fibers and composite materials based on them have found application in various branches of the construction industry. The field of use of carbon fiber plastics is growing and expanding, due to the combination of high strength (up to 7 GPa) and modulus of elasticity (200–700 GPa) with low density (1.7–2.0 g/cm³) and unique thermal, chemical, thermophysical, anti-corrosion, electrical and other properties of carbon fiber.

As a result of the scientific work of the specialists of the KTB group of companies [1], as well as many other studies [2–4], the following features of carbon composite fittings were determined.

1) **Tensile strength and modulus of elasticity.** Carbon-composite reinforcement with a diameter of 3 to 5 mm has an average tensile strength of 1920–2050 MPa, and the modulus of elasticity is approximately 360 GPa (See Table 1).

Table 1 – Research results of carbon-composite reinforcement of different diameters using carbon fiber with different module of elasticity and epoxy-based binders

Diameter of carbon-composite reinforcement, mm	The average value of tensile strength, MPa	The average value of elasticity, GPa	Cross-section of tensile strength, GPa
<i>Epoxy based</i>			
3	2050	236	368
4	2020	224	360
5	1920	220	364
<i>Elasticity based</i>			
3	1978	235	-
4	1950	225	-
5	1990	221	-

At the same time, for steel wire reinforcement, the tensile resistance and modulus of elasticity are lower (See Table 2).

Table 2 – Characteristics of steel wire reinforcement

Reinforcement class	Diameter, mm	Calculated strength for limiting conditions			
		Group 1		Group 2	Modulus of elasticity, MPa
		Tensile strength, GPa	Compression, GPa	Tensile strength, GPa	
Bp-1	3	375	375	410	170
	4	365	365	405	170
	5	360	360	395	170

2) **Lack of interaction with alkali.** Carbon-composite reinforcement loses strength by an average of 5% during prolonged interaction with alkaline solutions, which is an excellent indicator in comparison to steel reinforcement.

3) **Electrical characteristics.** Composite reinforcement, in comparison with steel, has high indicators of electrical conductivity: electrical resistance 10^{-2} – 10^{-6} Ohm·m [4], and the coefficient of thermal expansion of carbon fiber is: 0.8 – $1.2 \cdot 10^{-6}$ degrees-1 [5]. From the point of view of electrical engineering, carbon composite reinforcement is an electrical conductor with a relatively high resistance enclosed in a shell made of a polymer binder-dielectric.

Considering the high strength characteristics of composite reinforcement, as well as resistance to atmospheric and chemical influences, it can be concluded that structures reinforced with carbon composite reinforcement will have a much longer life cycle.

Theoretically, having a multiple safety margin and a higher modulus of elasticity, the use of carbon composite reinforcement can reduce the number of supports during the construction of bridges and overpasses, as well as increase the length of the floor spans. This solution reduces financial costs for materials and labor costs for workers, as well as speeds up construction.

The unique electrical characteristics of carbon-composite fittings allow it to be used as a heating element in concrete structures. Such a material can combat icing of dangerous sections of bridges and overpasses, as well as reduce financial costs and operational errors during the production of monolithic works in winter.

When analyzing existing scientific studies of carbon composite reinforcement, it can be concluded that this material has high potential for use in various fields of the construction industry. The use of composite reinforcement as a background reinforcement reduces multiple aspects of financial costs, as well as increases the service life of building structures.

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POWER ENGINEERING

Assessment of the Potential of BIM Technologies in Hydropower Construction

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Abstract: The hydropower sector in Russia is experiencing renewed interest due to the need for sustainable and clean energy sources. This paper explores the potential of using Building Information Modeling (BIM) technologies in hydropower plant design, construction, and operation to enhance efficiency and reliability.

Keywords: hydropower, BIM technologies, digital modeling, infrastructure

Hydropower remains one of the most promising renewable energy sources in Russia, given the country's vast water resources. In recent years, attention to the development of this sector has increased, supported by government investment programs targeting the construction of new hydroelectric power plants (HPPs), such as Krapivinskaya and Vilyuiskaya HPP-3. [1]

Modern technologies like Building Information Modeling (BIM) can play a vital role in improving the efficiency and precision of hydropower construction. BIM allows the creation of detailed virtual models that support all stages of a project, from planning and design to construction and maintenance.

In the context of HPPs, BIM enables for:

1. Design optimization – virtual models help determine the best layout and size for facilities;
2. Construction management – pre-construction modeling improves project control and coordination;
3. Maintenance and operation – models serve as tools for lifecycle management and predictive maintenance;
4. Performance analysis – BIM provides data for analyzing energy efficiency and risks;
5. Personnel training – virtual environments enhance worker safety and technical understanding.

Unlike standard construction projects, BIM for HPPs must account for unique components like dams, turbine halls, and reservoirs. Information

models progress through levels of development (LOD 100–400), each adding layers of technical and structural detail. [2]

While BIM use in Russian hydropower is still in early stages, companies like PJSC RusHydro are actively developing domestic solutions. Notably, the Nizhne-Bureyskaya HPP was a pilot project for BIM in 2016, followed by the Zaramagskaya HPP-1 in 2018. Initial results include error reduction, accelerated construction, and improved coordination across teams. [3]

Although regulatory frameworks are still forming, the benefits of BIM adoption in hydropower construction are evident. It allows for better cost estimation, improved quality control, and streamlined decision-making processes. [4]

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Improving the Emergency Response Module in Power Systems through *FLISR* and *PMU* Technologies

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Abstract: The reasons for malfunctioning of relay protection devices have been analyzed. The need to replace morally and physically obsolete devices has been formulated. Proposed is a joint implementation of the FLISR and PMU systems.

Keywords: automation of power system management, relay protection, power reliability, Fault Location, Isolation, and Service Restoration (FLISR), Phasor Measurement Unit (PMU)

Modern electric power systems face the challenge of ensuring reliable and sustainable network operation not only in normal operating conditions but also during disruptions such as changes in load parameters or emergency situations. Traditional relay protection methods based on local parameter measurements are often unable to provide rapid restoration of power supply after a disruption.

Failures in protective relays, false positives, unnecessary positives lead to increased instances of power loss for unaffected consumers. Configuration changes caused by emergencies require immediate response and optimal selection of isolation points for damaged sections and adjustments to the distribution network topology during system recovery. Therefore, human factors should be considered as one of the influencing factors in errors made while managing networks under high loads and time constraints.

To identify the causes of false positives, unnecessary positives and failures, data on the activities of relay protection devices for 2019–2024 were analyzed [1].

Based on the data, it can be concluded that – disregarding the year 2022 (which according to the Russian Power System Operator [1] is characteristic due to mass replacement of electromechanical equipment and insufficient speed of re-qualification of personnel for installation and maintenance) – the percentage of false detections is decreasing.

The calculation of the relationship between factors of wrong detections was done by calculating correlation coefficients r using Pearson's formula.

To estimate the value of the obtained correlation coefficients, the following ratio was used. With an absolute value of r in the range from 0.0 to 0.3, there is a weak link between the factors; with a value of r in the range from 0.3 to 0.7, there is a medium-sized link; if r is in the range from 0.7 to 1, then the link can be characterized as strong.

Based on the values obtained, it was possible to identify a relationship between the following factors (the correlation factor greater than 0.7) and to divide the resulting pairs of connections into two groups: technological factors and non-technological:

Technological Factors:

– the service life of electromechanical devices is such that it is necessary to replace, this is manifested in connection with a defect or malfunction of

secondary protection circuits and: defect or failure of electromechanical equipment; failure to perform maintenance within the prescribed time limits; failure to extend the service life or replace equipment;

- the influence of the non-performance of the regulatory work directly on the number of incorrect operations;

- failure to perform proper maintenance increases the risk of opening manufacturing defects;

- the need for quality installation, with compliance with all technical requirements, to avoid accelerated physical wear.

Non-Technological Factors:

- erroneous and incorrect actions of personnel and defects (shortcomings) of the project. The human factor is most evident in a system that has less automation and self-monitoring of the network.

On the basis of the above, the question of replacing electromechanical devices with modern (microelectronic) relay protection devices will allow to comprehensively solve many of the problems discussed, because on the basis of modern equipment it is possible to implement an automation system for management of energy system operating modes.

The joint application of the FLISR (Fault Location, Isolation, and Service Restoration) and PMU (Phasor Measurement Unit) technologies allows to significantly increase the efficiency of relay protection and accelerate the process of network recovery after accidents. The following main benefits of integrating these systems have been established.

Diagnostic accuracy. By using synchronized vector measurements, FLISR gets more accurate information about the network status, which allows for faster and more precise localization of the damage.

Optimization of recovery routes. The PMU provides data on the current status of all sections of the network, which allows the FLISR to choose the most efficient way to restore power supply.

Prevention of cascade outages. The joint operation of the two systems will allow to react quickly to changes in the network and prevent the propagation of emergency modes to neighboring areas.

Improved network resilience. The integrated system provides a higher degree of resistance to external disturbances through rapid response and adaptation to changing conditions. The implementation of the automatic network recovery system will reduce power recovery time for undamaged

consumers by 15–45 times faster than it is possible in a traditional network recovery system. And miss some phases of damage detection and repair on the accident site [2].

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Development of a Chatbot for the Tasks of Automatic Calculation of Relay Protection Settings

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Abstract: This article describes the development of a chatbot designed to help relay protection engineers perform various calculations.

Keywords: chatbot, relay protection, automation

Relay protection systems are vital components in modern electrical networks. They detect faults, such as short circuits, and quickly isolate damaged segments to prevent the failure from spreading. The correct configuration of protection devices is critical and often involves complex calculations that are both time-consuming and subject to human error.

The object of this study is the process of relay protection configuration in power systems. The goal is to support engineers by automating routine. The main tool proposed is a chatbot developed in Python, integrated with the Telegram messenger platform. The methods used in this project include algorithm design for differential protection and current transformer

saturation analysis, user interface development via Telegram Bot API, and Excel file handling for data exchange.

Telegram was chosen for its cross-platform accessibility, file transfer support, and intuitive interface. Engineers can use the chatbot on mobile or desktop devices without installing additional software or purchasing specialized licenses. This flexibility significantly expands access to automation tools in relay protection.

The chatbot consists of three main modules:

1. Transformer differential protection (Fully completed). This module calculates the settings for transformer differential protection. The user inputs transformer data (e.g., power, voltage, impedance), and the bot automatically computes recommended settings and generates a report.

2. Current transformer saturation time calculation (In development). Current transformers saturation can lead to incorrect operation of relay protection. This module analyzes current transformers parameters (provided via an Excel file) and calculates the saturation times using algorithms based on state standards [1], [2].

3. Short-circuit current calculation (Future function). This planned module aims to simulate short-circuits in power systems. Users will provide a network topology, and the bot will solve systems of equations to determine short-circuit currents at different nodes.

The novelty of the project lies in the application of a conversational interface for engineering calculations, which is not typically used in the power engineering domain. It makes relay protection design more accessible.

The results demonstrate that integrating automation with messaging platforms can improve the efficiency of relay engineers. The chatbot can be adapted to calculations of other protection settings, showing potential for broader application in the energy industry.

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RADIO ENGINEERING AND ELECTRONICS

Synthesis of the Z-Parameters of an Ideal Reactive Two-Port Network for Noise Figure Matching

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Abstract: This study addresses the critical issue of broadband matching in the design of low-noise microwave amplifiers (LNAs), which are vital for various applications, including telecommunications and radar technologies. It focuses on synthesizing the Z-parameters of an ideal reactive two-port network to achieve effective low-noise matching while minimizing reflection and loss across a wide frequency range. The research designs input and output matching networks. The results demonstrate alignment at specified frequency points. Future work will aim to adjust phase and noise factor deviations to meet the desired reflection criteria.

Keywords: noise figure matching, matching network, ideal matching two-port network, intrinsic parameters, Z-parameters, S-parameters

Broadband matching is especially important to consider when designing low-noise microwave amplifiers (LNA). In addition to the classical problem of broadband matching, which requires minimizing the level of reflection and loss over the entire frequency range, the problem of noise figure matching is also common. LNAs are widely used in various fields where it is necessary to amplify weak signals with minimal noise addition. In wireless networks, cellular and satellite communications, LNAs are used to amplify radio signals from antennas or transmitters before further processing. In medical technology, LNAs can be used in such types of diagnostics as MRI and ECG. In radar, the use of LNAs is necessary to amplify weak signals reflected from objects.

There are many works devoted to methods of synthesizing matching circuits of low-noise amplifiers [1, 2]. However, when designing broadband LNA, a number of difficulties arise related to the synthesis of matching networks, which must provide stable parameters over the entire frequency range. One of the biggest issues is impossibility of assessing the quality of the obtained solution. Therefore, the purpose of this study is the synthesis of the Z-parameters of an ideal reactive two-port network for low noise matching.

The problem of noise figure matching is to ensure that the input of the active component has the optimal value of the reflection coefficient corresponding to its minimum noise figure. To bring the problem to a form suitable for the application of classical matching methods, the intrinsic parameters of the two-port network, determined by the extrinsic parameters, are used to switch to the S-parameters. A low-noise CE3512K2 FET is used as the active element. Software is the AWR Microwave Office and VS Code CADs.

To demonstrate the results of the work done, an input matching network (IMN) is designed and graphs of its S-parameters (Fig. 1, Fig. 2(a)) and noise parameters (Fig. 2(b)) are obtained.

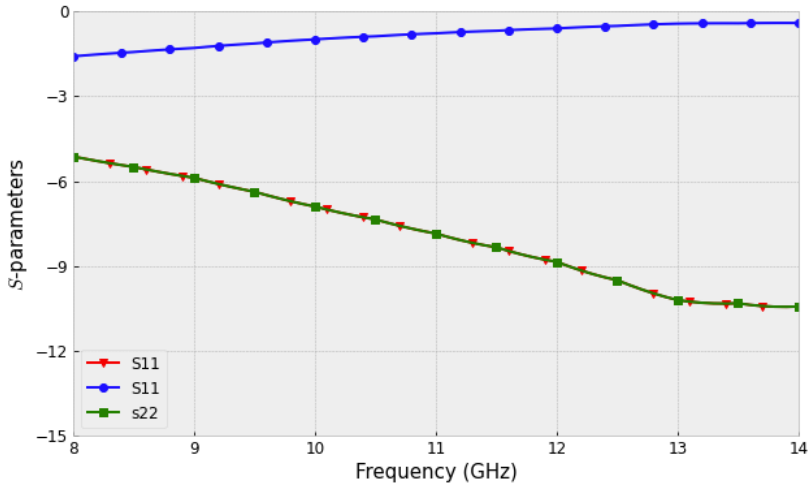


Figure 1 – Simulated S-parameters of IMN

Figure 2 shows the transistor noise factor, as well as the noise factor of the transistor and an input matching network in the form of a two-port network, the values of which completely match at all specified frequency points.

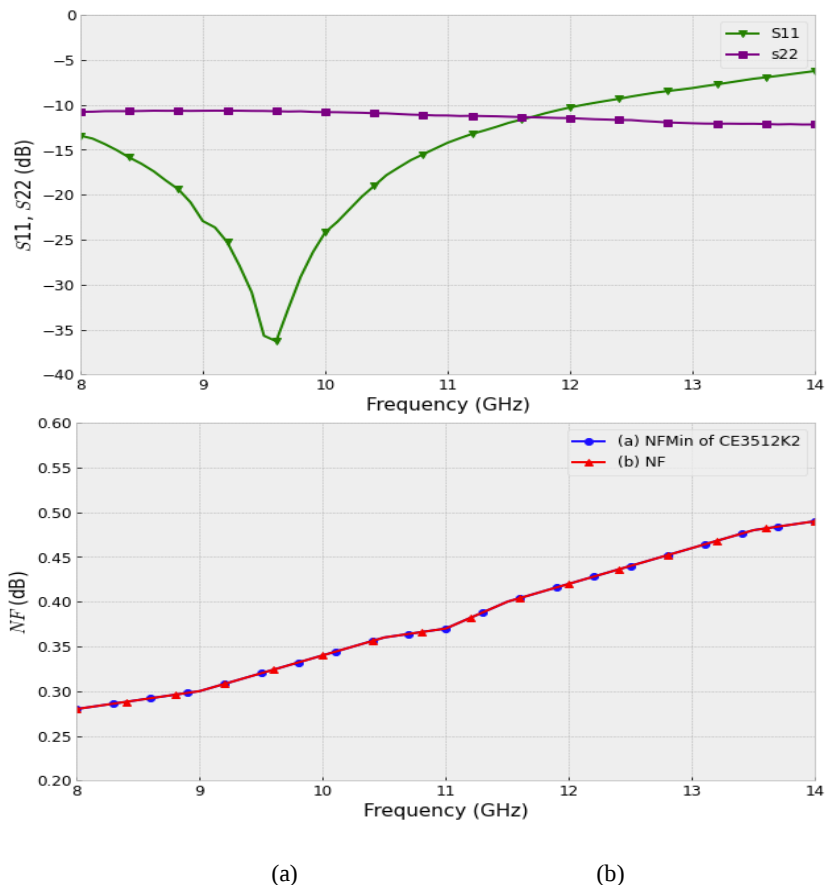


Figure 2 – (a) Simulated reflection coefficients of transistor with IMN, (b) Simulated noise factor of transistor and transistor with IMN

Since inductors are used to reduce the influence of internal parasitic components of a transistor, the program also provides calculation of the schematic with an inductor and it can be varied to the desired value.

The program is considered to calculate the Z-parameters of the matching networks that provide the lowest noise factor. Figure 3 depicts S-parameters of the schematic with the inductor $L = 0.1$ nH, as well as the two matching networks.

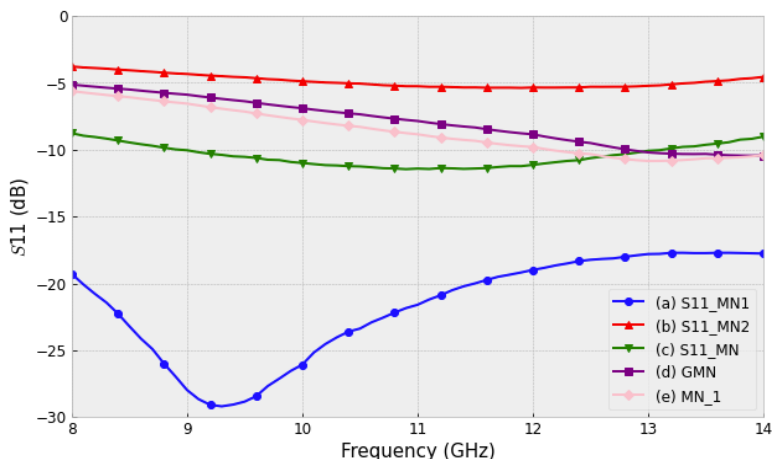


Figure 3 – Simulated S-parameters of (a) Transistor with IMN, (b) Transistor with OMN, (c) Transistor with IMN and OMN, (e) IMN; (d) GMN is optimum noise figure match of transistor

The equations obtained for the intrinsic parameters correspond to an ideal reactive two-port network, matching the active element in terms of the noise factor at all frequency points where the noise parameters are defined. The equations determine the form that the intrinsic parameters of the input matching network of the low-noise amplifier should tend to and can be used as a basis for synthesis procedures. The results obtained demonstrate the relevance and practical value of the study. As shown in Figure 3(c), these networks do not imply the optimal reflection coefficient. Therefore, the future work plan includes the varying of phase and noise factor deviation in order to get a reflection coefficient no higher than the specified one.

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Review of Laser Distance Measurement Methods Applied to Geodesy Tasks

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Abstract: This report reviews some methods of distance measurement that make use of optoelectronic technical approaches by applying those to solving geodesy tasks.

Keywords: laser distance measurement, lidar, space scanning, phase rangefinder, time-of-flight rangefinder, triangulation rangefinder, interferometer

The use of light flux as a carrier signal in the tasks of remote communication and space scanning has an advantage in angular resolution in comparison with radio and sound waves. This is due to the possibility of obtaining a narrow radiation pattern by adjusting the optical configuration of the device. Angular resolution is particularly important for surveying applications, construction, production line automation, etc. In order to optimize the design and manufacturing process, it is important to choose the right technical solutions for the task. Thus, for precision measurements at short distances (up to 3 meters) an interferometer is the best option, for long distances (kilometers) time-of-flight and phase measurement methods are suitable [1], etc.

Important physical factors of measurement, according to typical requirements of the technical specification in laser distance measurement [3] include such as dynamic range of measured distances, types of reflective surfaces, noise factors (stray light, thermal noise), device volume, refraction of light in the environment, etc. Important design parameters, based on the above are the following: transmitter power, receiver sensitivity, resolution of

optics, solid angle of view of optics, resolution of positioning and angle determination, and measurement speed.

Within the planned report, it is proposed to consider optical solutions based on focusing the laser beam at infinity, omitting solutions using vertical and/or horizontal sweep.

Electronics solutions involve the choice of laser type [2], photodetector [4], microwave oscillator and synthesizer frequency, optical radiation modulator, processor (depending on the task, usually FPGAs or microcontrollers are used), amplifiers and other following units.

This paper aims to popularize the application of optoelectronic solutions in distance detection.

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Derivation of Ratios for Calculating Complex Amplitudes of Signals to Form a Minimum Electric Field Strength

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Abstract: The article discusses a method of forming a minimum of the complex amplitude of the electric field strength by special distributing the initial phases in the transmitters of a linear antenna array.

Keywords: phased antenna array, initial phase, complex amplitude

Currently, phased antenna arrays are widespread in various areas of public activity. The electric field strength control within the radiation range of the antenna array is under great interest, particularly the formation of the strength minimum amplitude.

To form a minimum of strength, it is necessary to ensure the phases of the emitted signals at the focal point in such a way the sum of the complex amplitudes is equaled to zero (1.1):

$$A_{\Sigma} = \sum A_{m_i} \cdot e^{j(\varphi_i + \beta l_i)} = 0 \quad (1.1)$$

where A_m – emitted signal amplitude, φ – initial emitted signal phase, β – wave number, l – distance between focal point and emitter, and i – emitter number.

We consider the amplitude of the emitted signals is self-equal to each other, and it can't be equal to zero (1.2):

$$A_{m_i} = A_m \neq 0 \quad (1.2)$$

The final sum of complex amplitudes will be equaled to zero if the second factor is zero (1.3):

$$\sum e^{j(\varphi_i + \beta l_i)} = 0 \quad (1.3)$$

It follows that the signals with phases $\varphi_i + \beta l_i$ at the focal point have to compensate each other.

There is a situation (Fig.1) in which we want to form a minimum field strength at the focal point located at some distance from the geometric center of a linear antenna array on the optical axis.

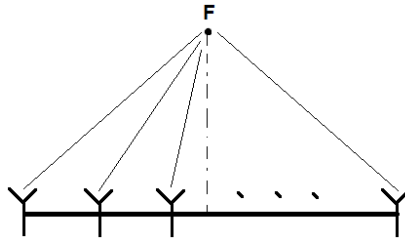


Figure 1 – Radiation direction scheme

Determining the distance from each emitter to the focal point (1.4) is:

$$l_i = \sqrt{F^2 + ((\text{ceil}(\frac{N+1}{2} - i - 1)) \cdot d + \frac{d}{2})^2} \quad (1.4)$$

where N – total number of emitters, d – distance between emitters, “ceil(...)” – function to round up to the nearest whole number.

Table 1 – Distances between emitters and focal point

Emitter №	1	2	3	4	5	6	7	8	9	10
Distance, m	2.018	2.011	2.006	2.002	2	2	2.002	2.006	2.011	2.018

The following formula was derived for the special phase distribution (1.5):

$$\begin{aligned} \varphi_{Fi} &= \frac{2\pi \cdot (i-1)}{N} + \pi \cdot \text{floor}\left(\frac{i}{\frac{N}{2}+1}\right) - \dots \\ &\dots - \left[\frac{2 \cdot 2\pi}{N} \cdot \text{floor}\left(\frac{i}{\frac{N}{2}+1}\right) \cdot \left(i - \frac{N}{2}\right) - \text{floor}\left(\frac{i}{\frac{N}{2}+1}\right) \cdot \frac{2\pi}{N} \right] \end{aligned} \quad (1.5)$$

where floor(...) – function to round down.

Table 2 – Phase distribution at the focal point

Emitter №	1	2	3	4	5	6	7	8	9	10
Phase	0	$\frac{2}{10}\pi$	$\frac{4}{10}\pi$	$\frac{6}{10}\pi$	$\frac{8}{10}\pi$	$\frac{18}{10}\pi$	$\frac{16}{10}\pi$	$\frac{14}{10}\pi$	$\frac{12}{10}\pi$	π

The phase of the emitted signals at the focal point due to the traveled distance l_i equals to $\varphi_i + \beta l_i$. By compensating the traveled distance with subtracting the term βl_i we can find the required initial phase of the signals for each emitter (1.6).

$$\begin{aligned} \varphi_{Fi} &= \varphi_i + \beta l_i \\ \varphi_i &= \varphi_{Fi} - \beta l_i \end{aligned} \quad (1.6)$$

Thus, the summation of complex amplitudes with uniformly distributed phases around the circumference at the focal point will be equal to a value

closed to zero, only if the focal point is located of the axis of antenna array geometric center. In other cases, the proposed phase distribution works with a large error, which does not meet the purpose of the study.

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Spectrometric Gamma Ray Logging while Drilling

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Abstract: This work tells about the process of developing a gamma ray spectrometry device during drilling. The gamma-ray spectrum obtained by the author independently, which correlates with the spectrum presented by an independent source, is presented.

Keywords: spectrometry, gamma-ray spectrometry, spectrometric gamma logging, logging while drilling, photoelectric multiplier (PMT), signal processing from PMT

There are various methods of oil and gas well logging during drilling. One of them is spectrometric gamma ray logging (SGL). However, SGL in the drilling process of domestic production does not exist. In this article the basic principles of SGL operation are considered, a simplified scheme of gamma radiation spectrum acquisition is given, gamma radiation spectra of various sources of ionizing radiation (SIR).

It is known that gamma radiation is a type of electromagnetic radiation with a very short wavelength, each gamma quantum has a certain energy. To detect this type of radiation, a scintillation unit is used – an assembly of a scintillation crystal and a photoelectron multiplier (PMT). The substance from which the scintillation crystal is made scintillates under the action of gamma rays, that is, to emit a beam of photons (light), and the number of

photons is proportional to the energy of the gamma quantum absorbed by the crystal substance. The light entering the PV is converted into an electrical signal. A simplified scheme for obtaining the gamma spectrum and estimating its parameters during gamma logging is shown in Figure 1.

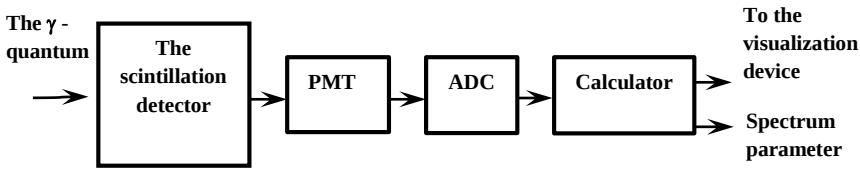


Figure 1 – Simplified scheme for obtaining the gamma spectrum and estimating its parameters

The natural gamma radiation of the rock is caused by three SIR – potassium, thorium and uranium. By determining the concentration of these three elements in the formation, the formation material can be attributed to a specific type of rock. The actual observed gamma-ray spectrum is shown in Figure 2 [1].

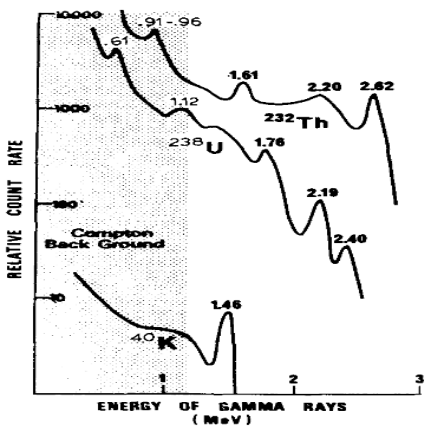


Figure 2 – The real spectrum of gamma radiation from potassium, thorium and uranium

Figure 3 shows a table of the dependence of the type of formation rock and the percentage of thorium, uranium and potassium in it.

Thorium, uranium and potassium contents of some igneous rocks			
Igneous Rocks	Th (ppm)	U (ppm)	K (%)
Acid intrusive			
Granite	19–20	3.6–4.7	2.75–4.26
Rhode Island ¹	21.5–26.6 (25.2)	1.32–3.4 (1.99)	3.92–4.8 (4.51)
Rhode Island ¹	6.5–80 (52)	1.3–4.7 (4)	5.06–7.4 (5.48)
New Hampshire	50–62	12–16	3.5–5
Precambrian	14–27	3.2–4.6	2–6
Average for			
granitic rocks	15.2	4.35	4.11
Syenite ¹	1338	2500	2.63
Acid extrusive			
Rhyolite	6–15	2.5–5	2–4
Trachyte	9–25	2–7	5.7

Figure 3 – The dependence of the type of formation rock and the percentage of thorium, uranium and potassium in it

In the course of the work, gamma-ray spectra of 3 elements were obtained, which were at the disposal of the author of the article: cesium – 137, europium – 152, cobalt – 60.

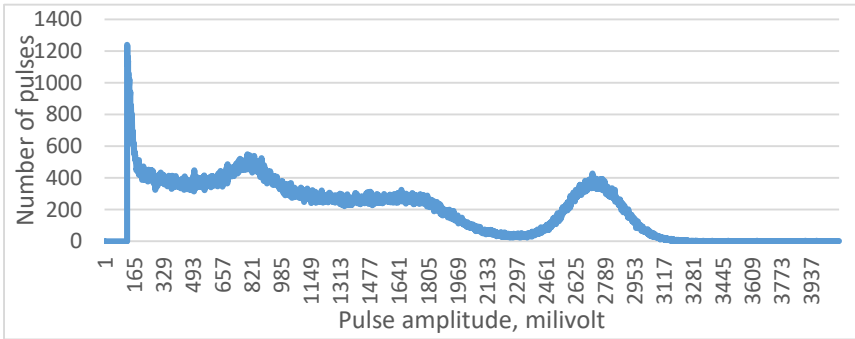


Figure 4 – The gamma-ray spectrum of a cesium source obtained by the author

Figure 4 shows the gamma-ray spectrum of a cesium source obtained by the author. The photo peak corresponding to 662 keV and the backscattering

peak are clearly visible on it, and the zones of the photoelectric effect and the Compton effect are clearly separated.

The obtained spectra correlate with the spectrum published by Idaho National Laboratory [2], which indicates the operability of the designed equipment of the FEU signal processor and the developed software.

Subsequently, it is necessary to solve the following tasks:

- 1) Thermal stabilization of the spectrum
- 2) Calibration of the device
- 3) Azimuthal dependence of readings
- 4) Field tests.

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Generator Control Unit with Bare Die Semiconductor Components Dmitriy Vedernikov

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Abstract: The text presents the results of thermal and power tests conducted on a prototype generator control unit implemented using SiC bare die semiconductor components.

Keywords: bare die semiconductor, generator control unit, excitation system

For an aviation power generation system based on a three-stage synchronous generator, a device called a GCU (Generator Control Unit) is required to regulate the excitation winding current of the exciter in response to changes in the stator current of the main generator [1]. This device is

powered by the voltage from the sub-exciter, which is independent of the operating mode and conditions of the main generator. Since the voltage level of the sub-exciter is typically higher than the maximum voltage required to supply the exciter's excitation winding, any step-down semiconductor converter is suitable for regulating this voltage. Modern aviation power supply systems are influenced by rapid technological advancements and increasing demands for reliability, efficiency, and equipment miniaturization [2]. Key trends include: increased onboard power capacity, stringent voltage accuracy and stability requirements, resilience to operational conditions, reduction in weight and dimensions, and compliance with aviation standards. In this context, an improved version of the GCU has been proposed.

Thus, the use of hybrid design and bare die semiconductor components represents an advanced approach that meets the current demands of aviation technology. As the voltage converter for supplying the exciter's excitation winding, a controlled H-bridge was selected, which can operate both as a single-phase voltage inverter and as a DC/DC converter.

During the development process, a mathematical and simulation model of the proposed GCU was constructed. The simulation results confirmed the necessity of creating a GCU prototype. The prototype was built (Fig. 1) using three stacked PCB: an aluminum power board mounted on a heatsink, a driver board placed above it, and a microcontroller board on top. The power section of the GCU was implemented using SiC bare die diodes (1.2 kV, 48 A) and SiC MOSFET bare die transistors (650 V, 20 A).

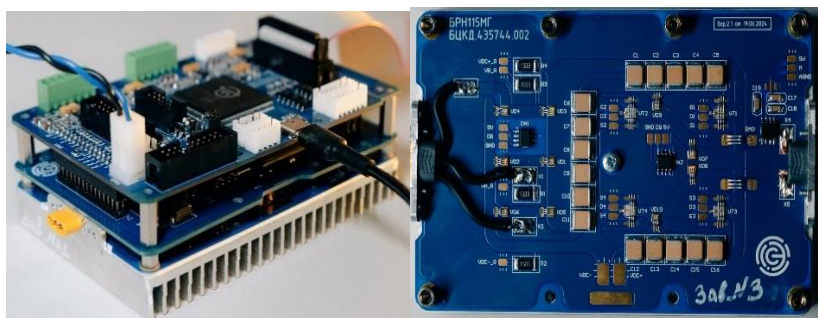


Figure 1 – The manufactured GCU prototype with bare die components

The heating tests were conducted without transistor operation. The surface temperature of the chips and the backside of the board for different DC link currents are presented in Table 1.

Table 1 – Results of the thermal experiment

Current, A	1	2	3	4	5	6	7	8	9
Front surface, °C	34	42	52	64	73	86	98	113	126
Back surface, °C	32	35	40	45	51	57	63	71	78

Electrical testing (Fig. 2) was performed with manual regulation of the GCU's output DC current. The achieved power output reached 500 W, which does not represent the limit for the power board. However, this achieved power level exceeds by more than two times the rated operating mode of conventional GCUs.

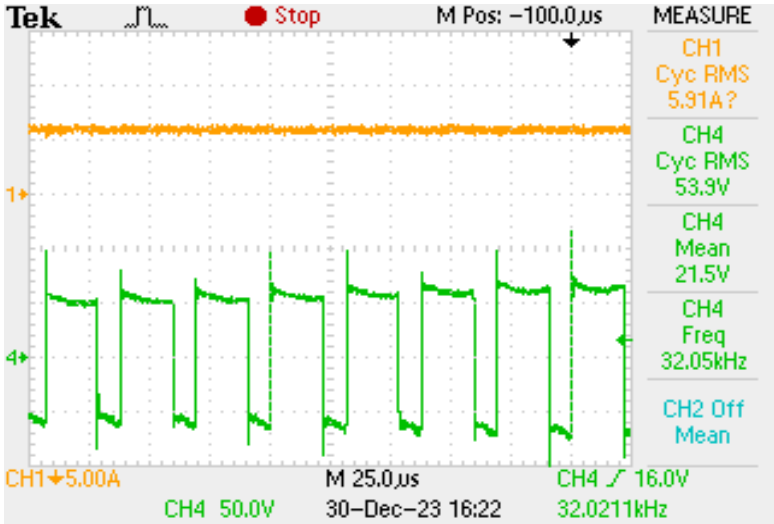


Figure 2 – Voltage and current waveforms at GCU output

Based on the experimental results, certain shortcomings were identified in the GCU's circuit design and microcontroller firmware, which are

currently being resolved. The use of bare die semiconductor components at power loads exceeding 1 kW necessitates forced air cooling. Several operational challenges associated with chip-scale components have been observed, including the requirement for protective encapsulation after PCB assembly, stringent handling and storage conditions, and the impracticality of replacement of defective elements.

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Performance Analysis of Isolated Resonant LLC Converter for Aviation Power Supply Systems **Sergey Velikher**

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Abstract: In this paper, a resonant LLC topology of a DC-DC converter with soft switching of power switch is considered and a comparison of the performance based on simulation model results is given.

Keywords: resonant converter, LLC, DC-DC converters, soft switching

At present, the aircraft power supply system is one of the main directions in aviation development. Modern aircraft use a wide range of electrical power generation and conversion systems. One of the connecting systems is a low-voltage DC network. Most electrical consumers are designed for a nominal DC voltage of 28 V. One example of this load is on-board control devices. To obtain a stable DC voltage, isolated voltage converters are used,

which must have high power density and small size to reduce the weight of the aircraft itself.

To reduce the weight of the inverter, it is necessary to increase the switching frequency of the power transistors. In this way, it is possible to achieve a smaller size of winding elements and capacitor capacitance, which will significantly reduce the final weight of the inverter. However, increasing the switching frequency leads to high dynamic losses, which affects the efficiency very significantly. Therefore, a resonant LLC converter circuit, which has the capability of smooth switching of power switches, was chosen as the topology to be investigated.

The developed circuit of the resonant LLC converter is shown in Figure 1 below. The converter consists of half-bridge inverter, resonant LLC circuit, diode rectifier and output filter. The half-bridge circuit has a smaller number of switches and control drivers compared to the bridge topology. However, half-bridge topologies suffer from high electromagnetic interference. The use of a resonant circuit, which will form a sinusoidal form of the primary winding current, will solve the problem of electromagnetic interference.

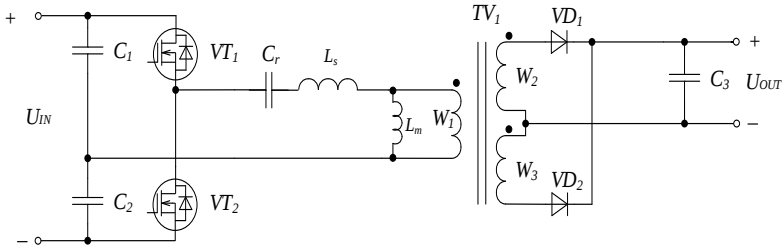


Figure 1 – A half-bridge resonant LLC converter

When designing a transformer, it is necessary to consider not only the number of turns of the primary and secondary windings, but also the required dissipation inductance L_s , which is necessary to create a resonant circuit, as well as the inductance factor, which depends on the magnetizing inductance L_m and the dissipation inductance (1):

$$m = \frac{L_s + L_m}{L_s} \quad (1)$$

The series-resonant frequency f_s (2) and parallel-resonant frequency f_p (3) are respectively expressed as follows [1]:

$$f_s = \frac{1}{2\pi\sqrt{L_s C_r}}, \quad (2)$$

$$f_p = \frac{1}{2\pi\sqrt{(L_s + L_m) C_r}} \quad (3)$$

In aircraft power supply systems, a value of 270 V is regulated on the high voltage DC side within the range of variation of $\pm 15\%$. The frequency of resonance of the converter was chosen $f_s = 250$ kHz. The inductance coefficient, based on expression (1), was chosen $m = 4.5$. The resonant circuit parameters $L_s = 7.52 \mu\text{H}$, $L_m = 26.33 \mu\text{H}$, $C_r = 53.85 \text{ nF}$. A silicon carbide MOSFET transistor C3M0065090J was selected as the semiconductors on the primary side and an ultrafast diode VS-60EPU02-N3 on the secondary side.

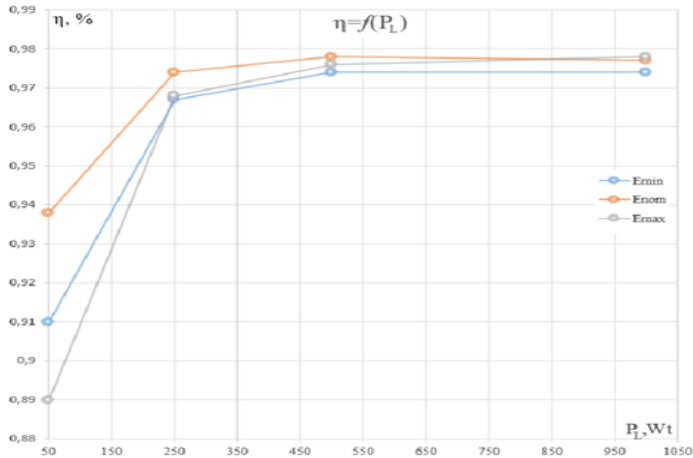


Figure 2 – Dependence of efficiency on output power at different input voltages

As a verification, a simulation model was drawn in PSIM with Level 2 semiconductor elements, in which the detailed characteristics of

semiconductors are taken into account. The obtained results can be seen in Figure 2 above.

Soft switching has significantly reduced dynamic losses in the transistors, and high-performance quality has been achieved. By increasing the frequency, the mass and power density can be improved, which is a major benefit for its aircraft applications. It is further possible to increase the efficiency by replacing the conventional diode rectifier with a synchronous rectifier with controlled switches. However, this method will increase the cost of the device and increase the complexity of control.

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GERMAN SESSION

Mittel zur Überwachung von Stromspeichersystemen

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Zusammenfassung: Dieser Artikel präsentiert ein drahtloses, modulares System zur Temperaturüberwachung in Stromspeichersystemen. Im Mittelpunkt steht die Entwicklung eines Controllers auf Basis des ESP32-Mikrocontrollers, der Daten von entfernten Temperatursensoren sammelt und über das MQTT-Protokoll an ein Überwachungssystem überträgt. Die Arbeit enthält sowohl theoretische als auch praktische Ergebnisse und vergleicht die entwickelte Lösung mit bestehenden Ansätzen. Ziel ist es, eine flexible, energieeffiziente und skalierbare Lösung zur Verbesserung der Betriebssicherheit von Stromspeichern zu bieten.

Schlüsselwörter: Stromspeichersystem, Temperaturüberwachung, ESP32, drahtlose Kommunikation, MQTT, Sensorintegration, Monitoring, Java, Energieeffizienz, Datenübertragung

Stromspeichersysteme spielen eine immer wichtigere Rolle im modernen Energiemanagement, insbesondere angesichts der Zunahme erneuerbarer Energiequellen. Die zuverlässige Überwachung solcher Systeme ist eine der Grundvoraussetzungen für deren sicheren und effizienten Betrieb. Ziel dieser wissenschaftlichen Arbeit ist es, ein System zur Überwachung der Temperatur in Stromspeichersystemen zu entwickeln, das entfernte Temperatursensoren integriert.

Frühere Arbeiten, sowohl vom Autor als auch von anderen Forschern, konzentrierten sich meist auf zentrale Messsysteme, die jedoch nicht immer skalierbar oder flexibel sind. Diese neue Arbeit bietet eine verteilte Lösung mit einem modularen Controller, der drahtlos Daten an eine bestehende Überwachungsplattform überträgt. Neu ist dabei die Kombination aus leicht programmierbarer Hardware, effizientem Datentransport und Echtzeit-Verarbeitung.

Zur Umsetzung der Aufgabe, einen Controller zur Integration entfernter Temperatursensoren in Überwachungssysteme von Stromspeichern (SPE) zu entwickeln, sind folgende Auswahlkriterien für den Mikrocontroller besonders wichtig:

- Unterstützung mehrerer Temperatursensoren: Möglichkeit zum Anschluss über Schnittstellen wie 1-Wire, I2C oder SPI. Dies ist notwendig, um Messdaten gleichzeitig von mehreren Sensoren an unterschiedlichen Punkten des Stromspeichers zu erfassen.
- Verfügbarkeit von Kommunikationsschnittstellen: Wi-Fi, Ethernet, Bluetooth oder LoRa für die Verbindung mit dem Überwachungssystem. Drahtlose Kommunikation ist besonders relevant, wenn Sensoren an schwer zugänglichen oder entfernten Orten installiert werden müssen.
- Energieeffizienz: Geringer Stromverbrauch zur Erhöhung der Zuverlässigkeit in autonomen Systemen. Dies erlaubt den Einsatz in energiebegrenzten Umgebungen mit Batterie- oder alternativer Stromversorgung.
- Rechenleistung und Speicher: Ausreichende Ressourcen zur Echtzeitverarbeitung von Sensordaten sowie zur Ausführung von Algorithmen wie Filterung, Anomalieerkennung und Datenaufbereitung.
- Kosten: Optimales Verhältnis zwischen Preis und Funktionalität. Bei begrenztem Budget müssen zuverlässige und gleichzeitig erschwingliche Komponenten verwendet werden.

Unter Berücksichtigung der genannten Anforderungen wurde der Mikrocontroller ESP32 als Plattform für den Controller ausgewählt. Diese Entscheidung basiert auf mehreren entscheidenden Vorteilen:

- Unterstützung aller notwendigen Sensor-Schnittstellen (I2C, SPI, UART, 1-Wire mittels Softwarebibliotheken).
- Integrierte Wi-Fi- und Bluetooth-Module, die eine drahtlose Datenübertragung ohne zusätzliche Hardware ermöglichen.
- Möglichkeit zum Energiesparmodus (Deep Sleep), was den Stromverbrauch bei langfristigem autonomen Betrieb deutlich reduziert.
- Hohe Leistungsfähigkeit und ausreichend Speicher, die es erlauben, mehrere Datenströme zu verarbeiten und komplexe Logik direkt auf dem Mikrocontroller auszuführen.
- Günstiger Preis sowie breite Unterstützung durch die Entwicklergemeinschaft, einschließlich zahlreicher Bibliotheken und Praxisbeispiele.

Daher wurde der ESP32 als die ausgewogenste Lösung ausgewählt, die

alle technischen Anforderungen des Projekts in Bezug auf Zuverlässigkeit, Funktionalität, Energieeffizienz und Kosteneffektivität erfüllt.



Ausbildung 1 – ESP32

Der Mikrocontroller wurde mit mehreren digitalen Temperatursensoren (Modell DS18B20) verbunden, die über das 1-Wire-Protokoll kommunizieren.

Die Sensoren erfassen regelmäßige Temperaturdaten an verschiedenen Punkten innerhalb des Stromspeichersystems. Diese Daten werden lokal vorverarbeitet, um Ausreißer zu filtern, und dann über das MQTT-Protokoll an einen Server gesendet. Die Daten werden in einer NoSQL-Datenbank (MongoDB) gespeichert und stehen dort zur weiteren Analyse bereit.

Die Software wurde in C++ geschrieben und besteht aus mehreren Modulen: Datenerfassung, Signalverarbeitung, Kommunikationsschnittstelle und Fehlerdiagnose. Ergänzt wurde das System durch ein grafisches Web-Interface zur Visualisierung der Temperaturverläufe.

Das entwickelte System soll in einer Testumgebung erfolgreich getestet werden. Zu den wichtigsten theoretischen Ergebnissen gehören:

- Stabile Messung über längere Zeiträume mit einer Abweichung von weniger als $\pm 0,5$ °C.
- Zuverlässige drahtlose Kommunikation im Bereich von bis zu 30 Metern ohne Datenverlust.
- Hohe Skalierbarkeit: Es können leicht zusätzliche Sensoren eingebunden werden.

Theoretisch wurden verschiedene Kommunikationsprotokolle miteinander verglichen. MQTT erwies sich als am geeignetsten für Anwendungen mit geringer Datenmenge und hoher Frequenz. Auch der Stromverbrauch des Systems im Energiesparmodus wurde analysiert und lag unter 10 mA.

Im Vergleich zu anderen Lösungen aus der Literatur [1, p.10] zeigt das vorgestellte System eine größere Flexibilität und einen geringeren Implementierungsaufwand. Während andere Autoren oft auf kabelgebundene Systeme setzen [2], bietet das hier entwickelte System eine mobile und drahtlose Alternative, die besonders für modulare oder dezentrale Energiespeicher geeignet ist.

Ein Unterschied liegt auch in der einfachen Wartbarkeit: Bei Ausfall eines Sensors muss nur das betroffene Modul ersetzt werden, ohne das gesamte System zu beeinträchtigen. Dies erhöht die Verfügbarkeit und reduziert Ausfallzeiten.

Das System eignet sich sowohl für industrielle Stromspeicher als auch für Heimspeicherlösungen. Es kann ohne große Änderungen in bestehende Systeme integriert werden und bietet somit eine hohe Praxistauglichkeit.

Zukünftig ist geplant, weitere Umweltparameter wie Luftfeuchtigkeit oder Spannung zu überwachen und mit der Temperatur in Beziehung zu setzen. Außerdem wird an einer energieautarken Version mit Solarversorgung gearbeitet.

Diese Arbeit demonstriert die erfolgreiche Entwicklung eines flexiblen Überwachungssystems zur Integration von entfernten Temperatursensoren in bestehende Stromspeicherlösungen. Das System basiert auf offenen Standards und kostengünstiger Hardware und liefert sowohl in der Theorie als auch in der Praxis überzeugende Ergebnisse. Es stellt damit eine sinnvolle Weiterentwicklung früherer Systeme dar und bietet Potenzial für breitere Anwendung.

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Automatisierung des technologischen Prozesses der Lagerung von Erdölprodukten

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Zusammenfassung: In dem Artikel wird der Prozess der Automatisierung des technologischen Prozesses der Lagerung von Erdölprodukten untersucht. Der Schwerpunkt liegt auf der Steigerung der Effizienz und Sicherheit der Lagerung. Es werden moderne Methoden zur Parameterüberwachung und Softwarelösungen betrachtet.

Schlüsselwörter: Automatisierung, Erdölprodukte, Tanklager, Industriecontroller

Die Automatisierung des Managementsystems eines Tanklagers auf der Grundlage moderner digitaler Technologien ermöglicht eine genauere Überwachung der Lagerparameter von Erdölprodukten, senkt die Betriebskosten und erhöht die Sicherheit, indem der Einfluss des menschlichen Faktors minimiert und der Betrieb der Ausrüstung optimiert wird.

Moderne Erdöllager sind komplexe technische Anlagen. Sie erfordern eine hohe Automatisierungsgenauigkeit für ein effektives Management der Lager- und Transportprozesse von Erdölprodukten. Messfehler können zu Rohstoffverlusten, Unfällen und Umweltverschmutzung führen. Traditionelle Überwachungsmethoden weisen oft eine hohe Fehlerquote und geringe Reaktionsfähigkeit auf. In diesem Zusammenhang ist die Automatisierung von Tanklagern eine aktuelle Aufgabe.

Zur Implementierung eines automatisierten Steuerungssystems wurden Studien zum technologischen Prozess der Lagerung von Erdölprodukten durchgeführt. Im Verlauf der Arbeit wurden technische Lösungen entwickelt, die auf die Verbesserung der Messgenauigkeit, der Parameterkontrolle und der Benutzerfreundlichkeit des Systems abzielen [1].

In der Anfangsphase wurde eine detaillierte Analyse der Struktur des Tanklagers durchgeführt. Es wurden die Schlüsselparameter identifiziert, die eine ständige automatische Überwachung erfordern, wie z. B. Füllstand, Druck, Temperatur, Dichte und Durchflussmenge. Diese Parameter spielen eine entscheidende Rolle bei der Sicherheit und Effizienz der Lagerung von Erdölprodukten.

Nach der Festlegung der Parameter wurden die technischen Automatisierungsmittel ausgewählt und begründet. Zur präzisen Messung und Überwachung wurden Industriecontroller sowie intelligente Füllstands-, Druck- und Temperatursensoren verwendet. Der Einsatz moderner Messgeräte erhöhte die Zuverlässigkeit der Daten erheblich und minimierte die Fehlerwahrscheinlichkeit.

Der nächste Schritt war die Entwicklung von Steuerungsalgorithmen. Die Prozesse der Parameterüberwachung und der Regelung der technologischen Betriebsmodi wurden optimiert, wodurch ein flexibles und zuverlässiges System der automatischen Kontrolle geschaffen wurde [2]. Durch die Einführung adaptiver Algorithmen kann das System schnell auf Änderungen der Betriebsbedingungen reagieren und potenzielle Notfälle verhindern.

Zur Umsetzung aller technischen Lösungen wurde die industrielle Steuerung programmiert. Die Integration mit Sensoren und Aktoren ermöglichte die automatische Regelung der Lagerparameter. Der Controller übernimmt Funktionen zur Datenerfassung, -verarbeitung und -übertragung an das Steuerungssystem sowie zur Ausführung von Befehlen zur Änderung der technologischen Parameter.

Ein Schlüsselaspekt des automatisierten Systems war die Schaffung einer benutzerfreundlichen Bedienoberfläche. Hierfür wurde das SCADA-System InTouch verwendet, das eine Datenvisualisierung und eine komfortable Steuerung des Prozesses ermöglicht. Die Bediener können in Echtzeit die Parameter des Tanklagers überwachen, Warnmeldungen über kritische Änderungen erhalten und Prozesse aus der Ferne steuern. In Abbildung 1 ist das Hauptfenster des Bedieners dargestellt.

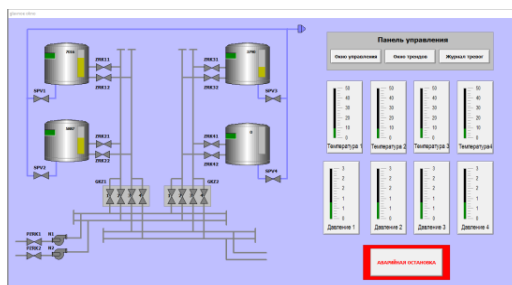


Abbildung 1 – Hauptfenster des Bedieners

Ein zusätzlicher Vorteil war die Einführung der Fernüberwachung und -steuerung des technologischen Prozesses. Bediener können die Systemparameter von jedem mit dem Netzwerk verbundenen Gerät aus überwachen, was die Bedienung erheblich vereinfacht und die Reaktionsgeschwindigkeit erhöht.

Das entwickelte automatisierte Steuerungssystem für Tanklager erhöht die Effizienz und Sicherheit der Lagerung von Erdölprodukten. Die Einführung moderner digitaler Technologien in das Management von Öllagern trägt zur Reduzierung von Verlusten, zur Erhöhung der Zuverlässigkeit der Ausrüstung und zur Verbesserung der Arbeitsbedingungen der Bediener bei. Geplant ist eine Erweiterung der Funktionalität zur automatischen Datenanalyse, zur Prognose von Notfällen und zur Optimierung des Energieverbrauchs.

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Einfluss der Dispergierparameter auf die Eigenschaften der Suspensionen Fe_2O_3 , MnCO_3 und ZnO

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Zusammenfassung: In dieser Arbeit wurde eine Reihe von Studien über den Einfluss der Dispersionsparameter von Ferrit-bildenden Oxiden auf die

Eigenschaften der erhaltenen Suspensionen durchgeführt. Die gemeinsame Einführung von Polyacrylsäure und 2-substituierter Ammoniumzitronensäure ermöglicht es, Suspensionen mit hoher Sedimentationsstabilität zu erhalten.

Schlüsselwörter: Keramik, Schleifen, oberflächenaktive Substanzen

Ferritwerkstoffe werden mit Hilfe der Pulvertechnologie hergestellt. Einer der wichtigsten Schritte ist das Nassmahlen von Pulvern, um stabile Suspensionen mit niedriger Viskosität zu erhalten. Um die oben genannten Eigenschaften der Suspensionen zu gewährleisten, werden verschiedene Dispergiermittel eingesetzt. Ziel der Arbeit war es, den Einfluss des pH-Werts des Mediums, der Ammoniumzitronensäure, der Polyacrylsäure und der Art der Vermahlung in Kugel- und Perlmühlen auf die Eigenschaften der Suspensionen zu bestimmen. Als Ausgangspulver wurden kommerzielle Pulver Fe_2O_3 , ZnO , MnCO_3 verwendet. Aus den Ausgangspulvern wurden wässrige Suspensionen hergestellt und in Kugel- oder Perlmühlen mit unterschiedlichen Verfahren gemahlen.

Zur Untersuchung der Eigenschaften der Suspensionen wurden folgende Mahlzeiten angewandt: 60, 180, 300, 600 und 1440 Minuten für die Kugelmühle, 20, 40 und 60 Minuten für die Perlmühle. Als Dispergiermittel wurden 2-substituierte Ammoniumzitronensäure (DAC) in einer Menge von 0,5 bis 2 mass.-% und Polyacrylsäure (PAA) in einer Menge von 0,02 bis 0,2 mass.-% sowie Mischungen davon verwendet. Die Dispergiermittel wurden vor der Einarbeitung der Pulver mit Wasser gemischt.

Tabelle 1 – Eigenschaften von Suspensionen mit verschiedenen Dispergiermitteln

№	ω , mass. %	Dispersionsmitte l	n, mass. %	μ , Pa·s	pH	h, mm
1	50	-	-	0,045	6	-
2		PAK	0,02	0,042	6	-
3		DAK	0,5	0,0238	8	3
4			1	0,0239	8	4,2
5			1,5	0,0241	8	5,4
6			2	0,0241	8	9,6
7		DAK+PAK	0,5+0,1	0,0236	7	0,6

Um den Einfluss von Menge und Art der Dispergiermittel auf die Sedimentationsstabilität gemischter Suspensionen zu bestimmen, wurde eine Reihe von wässrigen Suspensionen von Ausgangspulvern hergestellt. Die Dispergierung erfolgte in einer Kugelmühle für 5 Stunden. Die Menge des

Dispergiermittels und die Eigenschaften der erhaltenen Suspensionen sind in Tabelle 1 aufgeführt

In Tabelle 1 ist die Probenserie mit – №, Wassergehalt – ω , Dispergiermittel menge – n, Viskosität – μ , Partikelabsetzhöhe nach 5 Tagen Sedimentation – h gekennzeichnet.

Die Suspension ohne Dispergiermittel zeichnet sich durch eine hohe Viskosität von 0,045 Pa×s aus. Die Einführung von Polyacrylsäure in einer Menge von 0,02 mass.-% hat keine nennenswerte Auswirkung auf die Viskosität und den pH-Wert der Suspension.

Die Verwendung von DAK als Dispergiermittel führt zu einer 2-fachen Abnahme der Viskosität der Suspensionen, die mit einem Anstieg des Zetapotenzials von -7,15 auf -30,5 mV einhergeht. Eine Erhöhung der DAC-Menge führt zu einer leichten Veränderung der Viskosität, aber die Sedimentationsstabilität nimmt ab.

Die Verwendung von PAK und DAK führt zu einer Erhöhung der Sedimentationsstabilität der Suspension aufgrund der unterschiedlichen Stabilisierungsmethoden. Der Zusatz von Polyacrylsäure sorgt für eine sterische Stabilisierung, während der Zusatz von DAC eine elektrostatische Stabilisierung bewirkt. Bei diesen Stabilisierungsarten kommt es nicht zur Agglomeration von Pulverpartikeln in der Suspension [1].

Um den Einfluss der Mahldauer in Kugel- und Perlmühlen auf die Sedimentationsstabilität von Suspensionen zu bestimmen, wurden Versuche mit den in Tabelle 2 dargestellten Parametern durchgeführt. In der Tabelle wird die Mahldauer der Pulvermischung mit t_1 , die Menge an PAC – n(PAC), die Menge an DAC – n(DAC) bezeichnet.

Tabelle 2 – Mahlparameter und Eigenschaften der Aufschlammung

№	Verfahren zum Schleifen	t_1 , min	n(PAC), mass. %	n(DAK), mass. %	μ , Pa×s	pH	h, mm
8	Perlmühle	20	0,2	0,7	0,024	8	16,5
9		40					11,4
10		60					10,8
11	Kugelmühle	60			0,024	8	33
12		180					29,4
13		300					22,8
14		600					15
15		1440			0,036		3

Eine Erhöhung der Mahldauer führt zur Zerstörung von Agglomeraten und erhöht die Sedimentationsstabilität von Suspensionen. Nach Erreichen eines bestimmten Desagglomerationsgrades kann die Viskosität von Suspensionen aufgrund einer Erhöhung der Oberflächenenergie der Partikel ansteigen, was eine Erhöhung des Dispergiermittelgehalts erfordert [2].

Schlussfolgerungen

1. Hohe Sedimentationsstabilität und niedrige Viskosität von Suspensionen aus Fe_2O_3 -, ZnO - und Mn_2O_3 -Pulvern werden durch die Einführung von Polyacrylsäure und 2-substituiertem Citronensäureammonium im Verhältnis 1/5 erreicht.
2. Es wurde festgestellt, dass durch den Einsatz einer Perlmühle die Mahldauer um das 15-fache reduziert werden kann.

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Automatische Einstellung des Erregungsreglers eines Synchrongenerators

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Zusammenfassung: Der Artikel ist der Untersuchung von Methoden zur automatischen Steuerung von Synchrongeneratoren gewidmet, um deren Effizienz und Zuverlässigkeit zu verbessern. Es wird die Entwicklung eines digital-physikalischen Steuerungssystems eines Generators eines Schulkraftwerks mit Datenvisualisierung in MasterSCADA 4D vorgestellt, das die Umsetzung der automatischen Steuerung und die Überwachung der Generatorparameter in Echtzeit

ermöglicht. Außerdem wird in dem Artikel die Frage der schnellen und optimalen Abstimmung von automatischen Reglern mit Hilfe von linear-quadratischen Reglern (LQR) betrachtet.

Schlüsselwörter: LQR, SCADA, Labortisch, Synchrongenerator, automatische Regelung, Erregungsregelung

In der Energiewirtschaft sind heutzutage die Fragen im Zusammenhang mit der Verbesserung der Effizienz und Zuverlässigkeit von Synchrongeneratoren von besonderer Bedeutung. Die wichtigste Voraussetzung für den stabilen Betrieb von Stromversorgungssystemen ist die genaue Einstellung von Synchrongeneratorreglern wie dem automatischen Erregungsregler (AER) und dem automatischen Drehzahlregler (ASR). In der Regel arbeiten diese Regler als PID-Regler, die aufgrund ihrer verständlichen Struktur in automatisierten Regelsystemen weit verbreitet sind, aber sie haben einen Nachteil, nämlich die Schwierigkeit, optimale Abstimmungsparameter zu erreichen. Die Entwicklung intelligenter Ansätze [1] für die Reglerabstimmung verbessert nicht nur die Steuerung von Generatoren, sondern auch deren Fähigkeit, sich an veränderte Betriebsbedingungen anzupassen.

Der erste Teil meiner Arbeit besteht in der Erlangung praktischer Fähigkeiten in Form der Schaffung eines kostengünstigen und kompakten digital-physikalischen Steuerungssystems eines Generators eines Lehrkraftwerks mit einem interaktiven System zur Visualisierung und Verarbeitung von Befehlen. Zu den Hauptmerkmalen der entwickelten Anlage gehört das Vorhandensein von modernen Geräten der Leistungselektronik, von mikroelektronischen Geräten für ihre Steuerung, eines realen Generatorsatzes mit einem Antrieb in Form eines Gleichstrommotors und eines Steuerungs- und Überwachungssystems der Prozesse, das auf der Grundlage der Software MasterSCADA 4D mit der Implementierung in einer separaten SPS-Steuerung mit grafischer Visualisierung im Online-Modus der gesteuerten Parameter aufgebaut ist.

Diese Entwicklung wird es ermöglichen, auch andere Generatoren des Lehrkraftwerks zu nutzen und in Zukunft ein einheitliches digitales Kontrollsystem zu bilden, das es den Studenten ermöglicht, moderne Geräte zu beherrschen, neue Algorithmen der automatischen Kontrolle zu entwickeln und sie an diesem System zu testen.

Die Abbildungen 1 und 2 zeigen das Ergebnis der Arbeit in Form eines Labortisches, der die gleichzeitige Steuerung von zwei Synchrongeneratoren und die Überwachung ihrer Parameter in Echtzeit sowohl auf dem Display der Messgeräte als auch auf dem Bildschirm eines Computers ermöglicht, an den die Daten vom Labortisch über die serielle Schnittstelle RS-485 und das Datenübertragungsprotokoll ModbusRTU übertragen werden.



Abbildung 1 – Labortisch

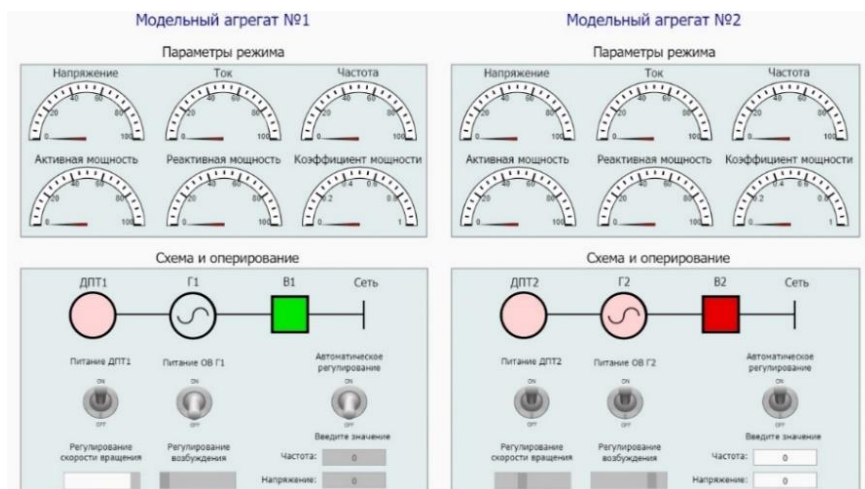


Abbildung 2 – Mnemonisches Schema des Steuerungssystems in der Software MasterSCADA 4D

Im zweiten Teil meines Beitrags schlage ich vor, das Thema der automatischen Regelung der Erregung von Synchrongeneratoren zu vertiefen, d.h. die bestehenden Lösungen in Form von PID-Reglern zu betrachten und eine neue Methode der Abstimmung von Erregungsreglern auf der Grundlage des linear-quadratischen Reglers LQR vorzuschlagen, die es ermöglicht, die gesamten Regelkosten und die Regelgeschwindigkeit zu minimieren. Die Anwendung von LQR in der Energiewirtschaft wird die Abstimmung von Synchrongeneratorreglern erheblich erleichtern [2].

Für die Zukunft ist geplant, den vorgeschlagenen LQR-Regler für die Erregungsregelung von Synchrongeneratoren zu synthetisieren und an einem in der Software Matlab Simulink erstellten digitalen Modell zu testen.

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Entwicklung und Erforschung von Methoden des maschinellen Lernens in diskreten Spielumgebungen

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Zusammenfassung: Der Beitrag untersucht die Q-Learning- und Deep-Q-Learning-Algorithmen in der diskreten Umgebung des Spiels „Tic-Tac-Toe“. Es wird bewertet, welche Methoden des Verstärkungslernen am effektivsten zur Entwicklung von Spielstrategien in diskreten Umgebungen beitragen können. Die Ergebnisse dieser Arbeit können zur Entwicklung von Spielagenten sowie für weiterführende Forschungen im Bereich der Künstlichen Intelligenz genutzt werden.

Schlüsselwörter: Q-learning, Deep-Q-learning, künstliche Intelligenz, diskrete Umgebungen, Spielstrategie, „Tic-tac-toe“, Agent

Verstärkungslernen (Reinforcement Learning, RL) wird häufig eingesetzt, um Strategien zu entwickeln, die auf der Interaktion mit der Umwelt basieren. Eine solche Anwendung ist die Entwicklung intelligenter Agenten, die sich an veränderte Spielbedingungen anpassen können. In diesem Beitrag werden Q-Learning und Deep-Q-Learning-Algorithmen für die Strategiegenerierung in der diskreten Umgebung des Spiels „Tic-tac-toe“ untersucht. Das Ziel der Arbeit ist es, eine vergleichende Analyse dieser Methoden durchzuführen und ihre Effektivität bei der Interaktion mit verschiedenen Gegnern zu bewerten, darunter zufällige, einfache und optimale [1].

Um die Wirksamkeit der Methoden zu bewerten, wurde eine Reihe von Experimenten durchgeführt, um die Leistung und Stabilität des Trainings von zwei Modellen im Spiel „Tic-Tac-Toe“ zu vergleichen. Das Modell gilt als trainiert, wenn sich seine Q-Werte und Neuronengewichte nicht mehr ändern, was darauf hindeutet, dass ein gewisses Maß an Optimalität bei der Entscheidungsfindung und Belohnungsmaximierung erreicht wurde.

Bei den Versuchen wurden drei Arten von Gegnern eingesetzt:

1. Ein zufälliger Spieler macht Züge auf zufälligen freien Feldern.
2. Ein einfacher Zufallsspieler wählt zuerst eine zufällige Zelle, aber wenn diese besetzt ist, wählt er die erste freie Zelle.
3. Der optimale Spieler (Minimax-Algorithmus) verwendet eine Strategie, bei der der beste Zug auf der Grundlage einer Bewertung aller möglichen Ergebnisse ausgewählt wird. YY

Die experimentellen Ergebnisse der beiden Modelle werden im Folgenden erörtert. Um die Lerndynamik zu bewerten, wurde eine Serie von 1000 Spielen mit untrainierten Q-Learning- und Deep-Q-Learning-Modellen auf einem 3×3-Feld gegen verschiedene Arten von Gegnern gespielt.

Aus den Ergebnissen der Dynamik des Deep-Q-Learnings lässt sich schließen, dass das Modell bei der Interaktion mit einem Zufallsspieler eine positive Lerndynamik aufweist, die sich in einer konstanten Zunahme der Anzahl der gewonnenen Spiele ausdrückt. Bei der Interaktion mit dem einfachen Spieler ist zu beobachten, dass das Modell eine größere Anzahl von Spielen benötigt, um sich an die Strategie anzupassen. Bei der Interaktion mit dem optimalen Spieler zeigt das Modell die geringste Dynamik, was darauf hindeutet, dass weitere Experimente erforderlich sind.

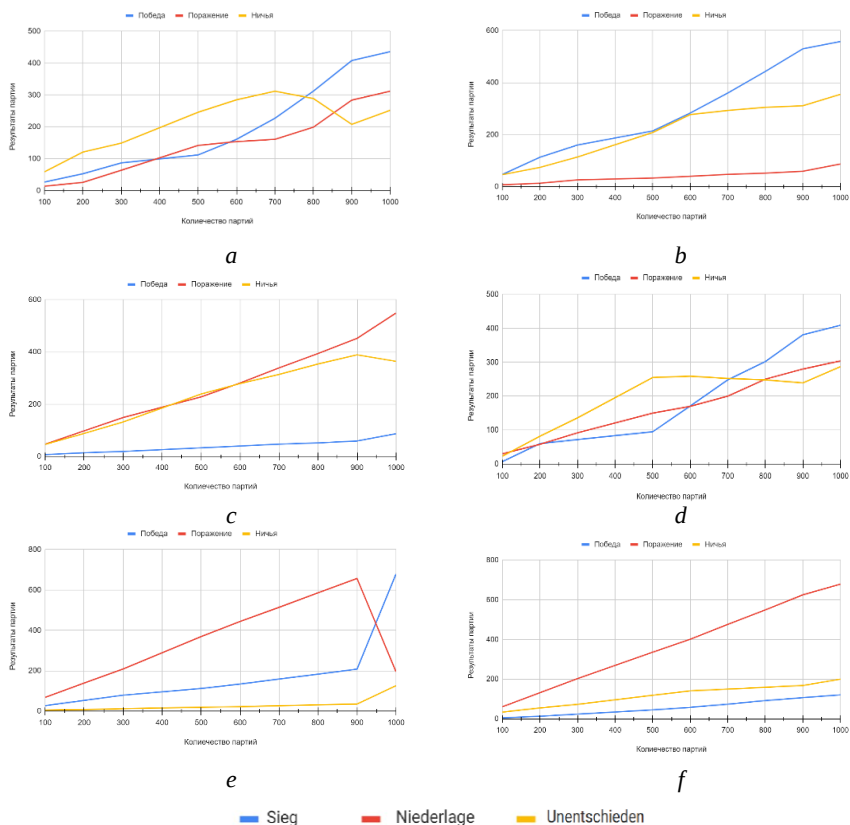


Abbildung 1 – Grafische Darstellung der Trainingsergebnisse des untrainierten Modells:
a – Q-Lernen mit zufälligem Gegner, b – Q-Lernen mit einfachem Spieler,
c – Q-Lernen mit optimalem Spieler, d – Deep-Q-Lernen mit zufälligem Spieler,
e – Deep-Q-Lernen mit einfachem Spieler, f – Deep-Q-Lernen mit optimalem Spieler

Die Ergebnisse der Spiele mit verschiedenen Gegnern für 1000 Episoden für die trainierten Modelle sind in Tabelle 1 dargestellt. Die Ergebnisse der trainierten Modelle zeigen, dass das Q-Learning bei einfachen Gegnern eine hohe Leistung erzielt und mehr Siege und weniger Verluste aufweist. Deep-Q-learning schneidet bei einfachen Strategien gut ab, aber die Anzahl der

Niederlagen steigt deutlich an, wenn mit Minimax gespielt wird, was darauf hindeutet, dass mehr Iterationen oder ein Tuning des Modells für Stabilität in komplexen Umgebungen erforderlich sind.

Tabelle 1 – Ergebnisse des Q-Learnings und des Deep-Q-Learnings mit verschiedenen Gegnern

Typ des Gegners	Q-Learning-Modell		Deep-Q-Learning-Modell	
	Gewinnen	Verlieren	Gewinnen	Verlieren
Zufallsspieler	867	39	772	103
Einfacher Zufallsspieler	800	83	709	89
Minimax	228	120	217	245

Die Arbeit zeigt, dass Q-Learning in einfachen Umgebungen effektiv ist, jedoch bei komplexeren Gegnern Grenzen aufweist, die weitere Optimierungen erfordern. Deep-Q-Learning hat eine bessere Generalisierungsfähigkeit, kann aber in komplexen Umgebungen instabil werden. Beide Algorithmen haben das Potenzial, effiziente Spielagenten zu entwickeln, aber ihre Leistung hängt von der Komplexität der Umgebung und dem Verhalten des Gegners ab.

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Sprachberaterin: Cheflektorin L.F. Luchikhina

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