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RECOMMENDED METHODOLOGICAL APPROACHES TO THE ORGANIZATION AND IMPLEMENTATION OF AN ENERGY-SAVING CONCEPT IN THE CONTEXT OF INCREASING THE VOLUME OF RENEWABLE ENERGY GENERATION CAPACITY IN UKRAINE

РЕКОМЕНДОВАНІ МЕТОДИЧНІ ПІДХОДИ ДО ОРГАНІЗАЦІЇ ТА РЕАЛІЗАЦІЇ КОНЦЕПЦІЇ ЕНЕРГОЗБЕРЕЖЕННЯ В КОНТЕКСТІ ЗБІЛЬШЕННЯ ОБСЯГІВ ГЕНЕРАЦІЇ ВІДНОВЛЮВАЛЬНОЇ ЕНЕРГЕТИКИ В УКРАЇНІ

Abstract. Modern challenges of energy security and the need to transition to sustainable development require the implementation of innovative solutions in the field of renewable energy. This article highlights key approaches to the organization and implementation of an energy-saving concept that contributes to the effective use of renewable energy sources in Ukraine. The current state of the energy infrastructure is analyzed, the main problems are identified, and effective algorithms for optimizing generation management are proposed. Special attention is

paid to intelligent forecasting systems, technologies for accumulating excess electricity, as well as the regulatory framework necessary for the formation of a sustainable energy policy of the country. Ref. 14.

Keywords: *energy efficiency, distributed generation, sustainable energy consumption, digital control algorithms, capacity balancing, prospects for "green" energy, innovative storage technologies, energy system transformation.*

Анотація. *Сучасні виклики енергетичної безпеки та необхідність переходу до сталого розвитку вимагають впровадження інноваційних рішень у сфері відновлюваної енергетики. У статті висвітлено основні підходи до організації та впровадження енергозберігаючої концепції, що сприяє ефективному використанню відновлюваних джерел енергії в Україні. Проаналізовано сучасний стан енергетичної інфраструктури, визначено основні проблеми та запропоновано ефективні алгоритми оптимізації управління генерацією. Особливу увагу приділено системам інтелектуального прогнозування, технологіям накопичення надлишкової електроенергії, а також нормативно-правовій базі, необхідній для формування сталої енергетичної політики країни.* Бібл. 14.

Ключові слова: *енергоефективність, розподілена генерація, стале енергоспоживання, цифрові алгоритми керування, балансування потужностей, перспективи "зеленої" енергетики, інноваційні технології зберігання, трансформація енергосистеми.*

Introduction. The world's energy sector is undergoing radical transformations caused by the rapid growth of energy consumption, changes in the structure of production and the need to reduce environmental impact. In the context of the global transition to environmentally friendly technologies and the abandonment of fossil fuels, countries are facing challenges in adapting their energy systems to new realities. Ukraine, which has significant potential in the field of renewable energy, has a unique opportunity to integrate modern technologies to improve energy security, reduce dependence on imported resources and minimize climate impact.

However, despite significant prospects, the implementation of a large-scale transition to renewable energy sources (RES) in Ukraine is accompanied by numerous barriers that hinder the dynamic development of the industry. The main problems remain:

- insufficient flexibility of existing energy networks, which complicates the integration of new generating capacities;
- limitations of modern energy storage technologies, which creates difficulties in balancing the energy system;
- slow adaptation of legislative norms and lack of incentive mechanisms to attract investments in renewable energy;
- low level of digitalization of power system management, which limits opportunities for optimizing energy flows.

Given these challenges, the urgent task is to develop a strategic approach to implementing comprehensive generation management algorithms that will ensure the sustainable development of renewables. This includes the use of advanced digital technologies, such as artificial intelligence (AI), big data (Big Data) and the Internet of Things (IoT), which allow for accurate forecasting of electricity

demand, increasing the efficiency of its distribution and optimizing the operation of electricity networks [1–5].

A systematic approach to the integration of renewable energy sources requires not only technological changes, but also reform of the legislative framework and the creation of favorable conditions for attracting international investors. Important areas of development are the implementation of smart grids, decentralized energy solutions, activation of the energy storage system market, as well as the expansion of financing mechanisms for innovative projects in the field of renewable energy.

Thus, strategic planning for the development of Ukraine's energy system should be based on a comprehensive approach combining technical, organizational, economic and legal aspects. The integration of modern digital solutions and the implementation of effective investment support mechanisms will allow Ukraine to strengthen its positions in the international "green" energy market, contribute to the decarbonization of the economy and ensure long-term energy security.

The purpose and objectives of the research. The main goal of the research is to develop a comprehensive system of algorithms and technological solutions to increase energy efficiency and expand the use of renewable energy sources in Ukraine.

To achieve this goal, the following tasks were set:

- to assess the current state of renewable energy use in Ukraine and its potential for further development;
- identify the main challenges and constraints that hinder the widespread implementation of RES;
- analyze modern capacity balancing technologies and their effectiveness in stabilizing the power system;
- to study the impact of digital control algorithms on optimizing electricity generation;
- to investigate modern methods of electricity storage and their economic feasibility;
- develop recommendations for improving the regulatory framework to stimulate the development of "green" energy.

Research material and results. Renewable energy in Ukraine is one of the key areas of transformation of the national economy aimed at increasing energy independence, reducing negative impact on the environment and integration into the European energy market. Today, the share of renewable energy sources (RES) in the overall energy balance of the country is growing, which is a positive signal for the further development of the industry. However, the process of its implementation is accompanied by numerous challenges, including technical, financial, organizational and regulatory aspects.

Solar energy is showing the fastest growth rates due to the falling cost of photovoltaic panels, growing interest among households and businesses, and support from the state and international partners. Wind energy, while having significant potential, faces challenges, including the need for complex logistics to

install turbines and the difficulty of predicting electricity production, which is dependent on weather variability. At the same time, bioenergy and small hydropower have the potential to improve energy security, but their share in the overall balance remains insignificant [6–9].

The main problems hindering the expansion of renewable energy in Ukraine:

- outdated power grid infrastructure, which does not allow for the effective integration of new capacities;
- lack of modern technologies for storing electricity, which makes it difficult to balance supply and demand;
- insufficient number of financial mechanisms that would stimulate investments in renewable energy sources;
- the need for changes to the regulatory framework to facilitate a rapid transition to sustainable energy.

Innovative technologies in renewable energy

One of the most promising areas of development is the introduction of digital technologies that can optimize energy production, storage and consumption. The use of artificial intelligence (AI) and machine learning opens up new opportunities to increase the accuracy of forecasting energy flows, which allows for more efficient management of power grid [6–10].

The main advantages of using AI in renewable energy sector are:

- improved forecasting of renewable energy production, reducing risks for grid operators;
- automated load distribution, which allows reducing energy losses;
- effective management of microgrids and decentralized electricity generators;
- application of deep learning algorithms for early detection of possible technical malfunctions in power systems.

Power system balancing

For the stable operation of Ukraine's energy network, it is important to develop intelligent energy flow management systems that ensure optimal energy distribution between consumers and producers.

Key balancing methods:

- development of smart grids that respond adaptively to changes in loads;
- creation of microgrids with the possibility of autonomous operation in emergency situations;
- using Internet of Things (IoT) technologies to monitor and manage distributed energy sources;
- integration of virtual power plants that unite small producers into a single system capable of flexibly responding to market needs.

Energy storage technologies

Efficient electricity storage is a critical element of a modern energy system, as it allows for the storage of excess energy produced during peak production periods and its use during times of high demand.

The most promising perspective growing technologies:

new generation battery systems based on grapheme structures and solid-state batteries;

- hydrogen technologies that allow converting electricity into hydrogen for further use;

- Power-to-X technologies that convert electricity into fuel (e.g. synthetic methane or liquid fuels);

- the use of pumped storage plants as an effective method of long-term energy storage.

Regulatory and legal regulation and prospects

Ukraine needs to update its energy legislation to provide more favorable conditions for the development of renewable energy. This includes creating transparent mechanisms to support investors, optimizing tariff policies, and promoting integration into the European energy system [10–16].

Main areas of regulatory policy:

- expansion of financial support mechanisms for investors in renewable energy;

- creating incentives for the development of decentralized electricity generation;

- active integration into ENTSO-E, which will allow increasing electricity exports and improving the stability of the power system;

- development of auction mechanisms for new renewable energy capacities, which will help attract international investors.

Thus, the development of renewable energy in Ukraine requires a comprehensive approach that covers not only technical and economic aspects, but also institutional changes, digital transformation and the creation of a favorable investment climate. Thanks to a strategic approach and effective state support, Ukraine can become a leader in the field of “green” energy in Eastern Europe.

Conclusions. Analyzing current trends in the development of renewable energy sources (RES) in Ukraine, we can come to an important conclusion – for the effective implementation of a comprehensive strategy, significant technical, organizational and regulatory changes are necessary. The challenges associated with the integration of “green” energy into the national energy system require not only financial investments, but also a strategic rethinking of approaches to planning, regulation and administration of the energy sector.

One of the key factors for the successful implementation of this strategy is the introduction of modern digital control algorithms that will optimize the generation, distribution and consumption of electricity. In particular, the development of smart grids, the introduction of automated monitoring and

forecasting systems for energy production from renewable sources will contribute to increasing the stability and efficiency of the power system. The use of artificial intelligence and big data will help to better predict the load on the network, minimize losses and improve the balancing of supply and demand.

Particular attention should be paid to expanding the electricity storage infrastructure. Modern storage technologies, including lithium-ion batteries, pumped storage power plants and innovative hydrogen systems, should become an integral part of the country's energy strategy. The development of such capacities will allow smoothing peak loads, ensuring the stability of energy supply and increasing the level of energy security of the state.

Modernization of the legal framework also plays an important role in stimulating the development of renewable energy. Improving legislation, creating favorable conditions for investors, introducing effective feed-in tariff mechanisms, and expanding state support programs will help accelerate the transition to sustainable energy. Introducing auction pricing mechanisms for electricity from renewables will make the market more competitive, reduce the financial burden on the state budget, and at the same time attract new participants to the sector.

Ultimately, a long-term strategy for the development of renewable energy sources should be based on innovation and environmental responsibility. Given Ukraine's huge potential in solar, wind and bioenergy, our country has every chance of becoming a key player in the "green" energy market in Europe. Implementing ambitious climate goals, focusing on international standards of sustainable development, developing international cooperation and exporting "green" energy – all this will contribute to strengthening the country's energy independence and its competitiveness at the global level.

Thus, only a comprehensive approach that encompasses technological innovations, energy market reform, expanding electricity storage capabilities, and improving legislation will allow Ukraine to make a qualitative breakthrough in the field of renewable energy.

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ОГЛЯД ПІДХОДІВ ДО ВИЗНАЧЕННЯ ТОПОЛОГІЇ ЖИВИЛЬНИХ ТА РОЗПОДІЛЬЧИХ ЕЛЕКТРИЧНИХ МЕРЕЖ

OVERVIEW OF APPROACHES FOR DEFINING THE TOPOLOGY OF POWER SUPPLY AND DISTRIBUTION ELECTRICAL NETWORKS

Анотація. Сучасні електроенергетичні системи розвиваються в умовах зростання попиту та впровадження нових технологій генерації. Традиційні методи проєктування не враховують нестабільність ВДЕ та необхідність автоматизації управління. Дослідження систематизує методи формування топології електромереж для підвищення їхньої ефективності та гнучкості. Розглянуто фактори впливу, типи топологій (радіальні, кільцеві, мережеві, мікромережі, Smart Grid) та алгоритми оптимізації (MST, PFA, GA, PSO, ACO). Використання цифрових двійників і ШІ сприяє підвищенню надійності та ефективності. Комплексний підхід, що поєднує класичні методи та інтелектуальні технології, забезпечує стабільність і масштабованість електромереж. Бібл. 6.

Ключові слова: топологія, електромережа, відновлювані джерела енергії, алгоритми оптимізації, штучний інтелект, smart grid, цифровий двійник.

Abstract. Modern power systems are evolving under increasing demand and the implementation of new generation technologies. Traditional design methods do not account for the instability of renewable energy sources (RES) and the need for automated control. This study systematizes methods for power grid topology formation to enhance efficiency and flexibility. The study examines influencing factors, topology types (radial, ring, mesh, microgrids, Smart Grid), and optimization algorithms (MST, PFA, GA, PSO, ACO). The use of digital twins and artificial intelligence (AI) improves reliability and efficiency. A comprehensive approach combining