

ASPECTS OF THE FURTHER DEVELOPMENT OF PHOTOENERGY ACCORDING TO THE MATERIALS OF THE SCIENTIFIC AND PRACTICAL CONFERENCE «RENEWABLE ENERGY AND ENERGY EFFICIENCY IN THE 21st CENTURY» 2023

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The main results of reports at the "Solar Energy" section were considered and summarized, in particular, one of the areas of solar energy – photoenergy. Specialists from Ukraine, Poland, the Czech Republic and the Republic of Uzbekistan took part in the work of the section in this area. A total of 22 reports were presented, which related to the issues of increasing the energy efficiency and reliability of the operation of solar power plants, the peculiarities of the operation of solar autonomous power plants and installations, new technologies for the production of photo modules, etc. For the most part, the reports focused on the creation and operation of energy-efficient and reliable solar power plants.

Key words: electric energy, solar power plant, photovoltaic module, energy efficiency, artificial intelligence, photovoltaic technologies.

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АСПЕКТИ ПОДАЛЬШОГО РОЗВИТКУ ФОТОЕНЕРГЕТИКИ ЗА МАТЕРІАЛАМИ НАУКОВО-ПРАКТИЧНОЇ КОНФЕРЕНЦІЇ «ВІДНОВЛЮВАНА ЕНЕРГЕТИКА ТА ЕНЕРГОЕФЕКТИВНІСТЬ У ХХІ СТОЛІТТІ» 2023

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Розглянуто та узагальнено основні результати доповідей на секції «Сонячна енергетика», зокрема одного з напрямів сонячної енергетики – фотоенергетики. У роботі секції з цього напрямку взяли участь фахівці з України, Польщі, Чеської Республіки та Республіки Узбекистан. Всього було представлено 22 доповіді, які стосувалися питань підвищення енергоефективності та надійності роботи сонячних електростанцій, особливостей експлуатації сонячних автономних електростанцій та установок, нових технологій виготовлення фотомодулів тощо. Здебільшого в доповідях висвітлювалися питання створення та функціонування енергоефективних і надійних сонячних електростанцій.

Ключові слова: електрична енергія, сонячна електростанція, фотоелектричний модуль, енергоефективність, штучний інтелект, фотоелектричні технології.

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Introduction. During the XXIV International Scientific and Practical Conference "Renewable Energy and Energy Efficiency in the 21st Century" (Ukraine, Kyiv, May 18–19, 2023), the "Solar Energy" section highlighted aspects of the further development of one of the areas of solar energy – photoenergy in Ukraine, Poland, the Czech Republic, and the Republic of Uzbekistan [1]. At the conference in this field of solar energy, 22 reports were presented, which related to the issues of increasing the efficiency and reliability of the operation of solar power plants, the features of the operation of low-power solar (grid and autonomous) power plants and installations, new technologies for the production of photo modules, etc.

The purpose of the publication is to summarize the research materials that were presented in the reports, and to highlight the features of the further development of photoenergy as a component of one of the areas of renewable energy.

Analysis of the content of reports. The current problems of traditional energy are related to the limited and uneven distribution of energy resources on the planet, the imperfection of traditional energy technologies and the need to solve the global tasks of providing energy to mankind in the future, related to the complete depletion of organic fuel reserves and environmental safety issues.

To solve these problems, the European Union (EU) adopted a strategic plan in 2019 – the European Green Course [2], which is a roadmap for measures to achieve an efficient, sustainable and competitive economy that will ensure the creation of a climate-neutral continent by 2050. One of the key areas of the European Green Course is clean energy, which includes renewable sources. Increasing the energy efficiency of power systems, creating conditions for sustainable and comprehensive growth and development are the most cost-effective ways not only to reduce emissions of greenhouse gases and other substances that pollute the environment, but also to reduce import dependence and strengthen energy security. Today, Europe's policy is aimed at maximally reducing its dependence on Russian fossil fuels by increasing the rate of development of renewable energy sources (RES). Ukraine is a direct part of the European energy system and must ensure the fulfillment of international obligations to increase energy efficiency and decarbonize the economy in accordance with the Association Agreement with the EU, the Paris Agreement, the Treaty on the Establishment of the Energy Community [3], the European Green Course, a number of EU directives, etc.

Photoenergy is one of the most promising areas of using RES, the advantage of which is the ability to directly convert the energy of solar radiation into electrical energy. Ecologically clean solar energy is the most accessible and practically inexhaustible energy resource from all renewable sources, the use of which is effective in most areas of the Earth's surface. The high energy potential of solar radiation in Ukraine is sufficient for the introduction of electric power equipment almost throughout the country. According to the results of scientific research, the theoretical installed

capacity of solar power plants (SPPs) is 82,768 MW, and the annual potential of generating electrical energy of SPPs in Ukraine is about 100 billion kWh/year [4, 5], i.e. Ukraine has sufficient capacity to replace a significant part of Russian energy resources with its renewable generation.

The resolution of the Cabinet of Ministers of Ukraine dated July 30, 2021, in accordance with the international obligations to reduce emissions in the Nationally Determined Contributions (NDC2) to the Paris Climate Agreement by 2030, provided for a reduction of greenhouse gas emissions by 65% of the 1990 level [6]. One of the directions in accordance with the higher goals set by Ukraine at the international level regarding the reduction of harmful emissions in the NDC2 is photoenergy – a significant share in the field of electricity production should be solar power. In 2021, the National Economic Strategy of Ukraine until 2030 was adopted, according to which the share of renewable energy sources should increase to 25% in the country's electricity balance by 2030 [7]. These requirements correspond to the "scenario" of keeping global warming below 2 degrees by 2050 (REmap Case) of the program for the further development of the renewable energy sector, published in 2019 by the International Renewable Energy Agency (IRENA) in the report "The Future of Solar Photovoltaic Energy: Development, investments, technologies, integration into energy systems and socio-economic aspects" [8]. According to IRENA forecasts, solar energy will play a central role in the energy transition, the main components of which are renewable energy and energy efficiency improvement [9]. To implement the climate goals established by the Paris Agreement, a significant increase in photovoltaic generation is foreseen: the agency expects that by 2050, the share of large-scale projects will be equal to about 60% of the total installed capacity of photovoltaic systems in the world [8].

In the last years before the full-scale war, the photo-energy industry of Ukraine developed quite intensively, despite some market instability and deterioration of the investment climate. According to the results of 2021, the installed capacity of the solar energy sector of Ukraine reached 7,586.25 MW (excluding those SPPs located in temporarily occupied territories). In 2021, the share of electricity generated from RES reached 8.1% or 12.8 TWh, of which 56% is due to solar radiation. However, starting from 2020, an active pace of development was observed only in the SPPs segment for private households, the capacity of which increased by 426.1 MW in 2021. The total installed capacity of all household solar systems reached 1205.1 MW at the end of the year [10].

The situation worsened significantly after the full-scale invasion. According to experts in the field of energy, at the end of October 2022, about 45–50% of SPPs, most of which are located in the south of the country, were decommissioned. The war caused significant losses to the industry, the share of RES in the total volume of electricity production fell almost twice: by 2022, this indicator was 13.4%, now it is 5–6% [11].

At the current stage of the development of photoenergy, the problems of efficient use of solar radiation energy due to the use of advanced technologies come to the fore. The conference reports were devoted to the solution of these issues, which are impossible without the development of new technical and technological scientifically based solutions.

Modern photoenergy technologies are quite effective and reliable. Today, solar modules can generate electricity with an efficiency of about 20%. In addition, the cost of innovative technologies, which used to be expensive, is reduced. The use of double-sided solar modules is rapidly developing, which can generate 10–15% more electricity than single-sided ones, which significantly reduces the area for their installation. Solar tracking systems are becoming more competitive, in which two main types of dynamic tracking systems are distinguished - uniaxial and biaxial. A single-axis tracking system can increase productivity by 15–20% compared to a stationary system, a two-axis system by 35–50% [12]. Research in this field continues, so we can expect additional developments and improvements in technology to improve the efficiency of solar power plants.

At the conference, methods of achieving maximum energy efficiency and reliability of solar tracker power plants were discussed in reports [13–17]. Examples of the use of artificial intelligence in tracking SES [13, 14] deserve attention, which is an effective tool for ensuring their maximum productivity. The use of artificial intelligence will make it possible to automatically adjust the position of the photomodules relative to the sun, reduce the influence of undesirable factors on the operation of the equipment, increase the reliability and durability of the equipment, as well as reduce the impact of shadows and other obstacles on the operation of the photomodules. Various methods are considered, such as the use of neural networks, machine learning and optimization algorithms, etc. Specialists from the Republic of Uzbekistan shared their experience in using a smart system to increase the energy efficiency of SPPs [15]. The calculation of the selection of components for the study of energy efficiency indicators of a photovoltaic installation using the SMART system, which is used to achieve the optimal supply of electric energy for an autonomous object, is given. Reports [16, 17] also presented the results of research into the operation of tracker photovoltaic systems, showing their advantages in comparison with stationary systems. The obtained data make it possible to predict an increase in the effective operation of the photovoltaic plant due to the formation of the profile of the solar energy input with the help of tracking systems and module fields of different orientations. The experience of operating a rooftop photovoltaic station with a capacity of 2.5 kW with a hybrid inverter is presented in the report [18]. The conditions for the generation of excess electricity into the network have been determined. The equipment and software for the implementation of the algorithm based on the comparison of network and hybrid inverter voltages have been developed, the conditions for optimal consumption and

generation of electricity in network and autonomous modes have been determined.

In a number of reports, proposals were presented regarding the practical application of power systems based on photovoltaic modules, which is very relevant for Ukraine, especially in the conditions of martial law. A report on the design of a photovoltaic system with the use of software was devoted to the issue of power supply of temporary modular towns for the residence of war victims (shelters) [19]. Photoelectric system for electricity supply of the shelter is a complex task, which includes the correct selection of electrical parameters of individual components, taking into account environmental conditions, the load schedule of the shelter and electrical devices in its composition. Recommendations for the use of electrical appliances will help to increase the efficiency of operation of the photovoltaic system for power supply of shelters. A comparative analysis of the requirements for a hybrid photovoltaic plant and an electric generator with an internal combustion engine to meet the needs of electricity in wartime conditions was given [20]. Features of the operation of power transformers to ensure the reliability of the power system and the photoelectric plant in its composition in the conditions of war were considered in the report [21]. The use of dynamic switching of cells in electric energy accumulators allows you to quickly change the topology of the electric energy accumulator to obtain the required output parameters, which gives advantages in controlling the generation, accumulation and consumption systems in the process of direct application and, as a result, increases the efficiency of the accumulator [22].

In the reports of scientists, attention was paid to the technical capacity of the energy system to balance the growing capacities of SPPs. In particular, the factor of power losses, which are caused by overflows in the electrical networks of electrical systems from renewable sources, which reduces their energy efficiency, was estimated. Determination of power and electricity losses in electrical networks and its separate branches, which are caused by individual photovoltaic plants and their groups, makes it possible to evaluate and take into account the impact of photovoltaic plant on the electricity balance, taking into account the losses, which can be used for operational planning of the electricity balance in the energy system [23]. Assessment of sensitivity to changes in meteorological parameters for forecasting electricity generation schedules by photovoltaic stations by analyzing the results of a field experiment at an operating solar station with a capacity of 3.2 kW is presented in the report [24]. An overview of the existing methods of forecasting the photovoltaic power of solar panels was considered in the report [25], where the main forecasting methods and models were described and classified, and their comparative analysis was made with an assessment of the accuracy of software calculation methods.

Today, the global market is dominated by crystalline silicon (c-Si) and thin film technologies. However, solar panel manufacturers are constantly improving their production

technologies, new more efficient and reliable photovoltaic modules appear, the use of which makes it possible to increase generation and extend their service life. The report [26, 27] was devoted to the review of new technologies for the production of photovoltaic modules. The report [26] presented an overview of new types of photomaterials that allow to increase the efficiency of both rooftop and ground solar power plants, considered their features, differences and advantages compared to photomaterials that are currently actively used. The report [27] provides a comparison of n-type and p-type photovoltaic modules, which are gaining more and more popularity, their main advantages and disadvantages are given.

The reports of Uzbek specialists highlighted the results of research into new technologies for the manufacture of solar cells [28-30]. In particular, new materials and structures were considered as a means of increasing the efficiency of ZnO/Si and TiO₂/Si heterojunction solar cells [28]. A report [29] was devoted to the study of solar cells based on gallium arsenide (GaAs), which are called cascade, multi-junction or tandem. Solar panels built from such elements operate in most bands of the solar spectrum and have an efficiency of over 30%. To date, the technology of recrystallization of thin-film amorphous or fine-crystalline films has developed high-efficiency solar cells intended for use in solar panels with solar radiation concentrators.

At the conference, attention was also paid to the issue of using photoenergy potential for the production of green hydrogen. The implementation of scientific research in the direction of technical improvement and cheapening of solar and hydrogen energy technologies will allow to transform the ways of carbon-free production, supply, storage and consumption of energy, improve the level of energy efficiency and deep decarbonization of vehicles, construction and industry of the country [31].

Conclusions. Implementation of the best models of photoenergy equipment, determined on the basis of analytical studies of world and domestic experience, for the effective use of photo-energy is one of the priority tasks both at the current stage of development of the economy of Ukraine and for the long-term post-war perspective.

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