

## ANNOTATION

of PhD thesis for the degree of Doctor of Philosophy (PhD) in specialty  
6D071800 – «Electric Power Engineering»

**Saulesh Minazhova**

### **PRINCIPLES OF AN INTEGRATED APPROACH TO INCREASING THE EFFICIENCY OF RENEWABLE ENERGY COMPLEXES OF AUTONOMOUS POWER SUPPLY**

**Relevance of the work.** The annual increase in electricity consumption due to the rising standard of living, the development of technology and industry, and globalization make the energy industry one of the most important points throughout the world. In addition, the issue of climate change and environmental pollution is acute. To overcome difficulties with energy supply and reduce emissions, current sustainable development policies should be aimed at creating a more decentralized, balanced and environmentally friendly energy supply system, which will include various types of renewable energy sources (RES) [1].

Fundamental to achieving the above goal is the Law “On Supporting the Use of Renewable Energy Sources” adopted by the Head of State in 2009 [2]. The law contributed to the rapid introduction of renewable energy sources into the electrical grid of Kazakhstan, defining the principles of a «green» economy as the direction of future development.

Another initiative to support the development of RES in Kazakhstan was the «Concept for the transition of the Republic of Kazakhstan to a green economy until 2050», adopted in 2013, within the framework of which the state designated the shares of RES in the total volume of electricity production: 3% by 2020, 30 % by 2030 and 50% by 2050 [3].

Since Kazakhstan is located in the very center of the Eurasian continent, the country has great potential for wind, solar and water energy. According to expert data, the technical potential of wind energy is 929 billion kWh per year, the potential of hydro and solar energy is 8 billion kWh per year and 2.5 billion kWh per year, respectively [4]. Despite the significant potential of wind, these resources cannot be developed and used on a sustainable basis due to a number of technical, economic and logistical barriers. In this regard, the solar industry is actively developing in the country, since the construction and maintenance of solar photovoltaic systems is less expensive, safe, easily transported and quickly pays off. As a result, in Kazakhstan from 2019 to 2022, the total installed capacity of solar power plants (SPP) increased from 542 MW to 1148 MW and amounted to 48% of the total share of installed capacity by renewable energy sources in the country [5]. This trend in the development of solar systems is observed not only in Kazakhstan, but also in other developed countries of the world.

To date, Kazakhstan has fulfilled its obligations to increase the share of RES in the energy balance of consumption, reaching a 3% level in 2020. Experts explain

this by the fact that in 2020, large SPPs were actively put into operation, the construction of which was suspended due to the outbreak of the COVID-19 pandemic in 2019. However, now the country faces an even more important responsibility - to increase the share of renewable energy sources to 30% by 2030. To achieve this, the construction of large-scale RES is not enough, but it is also necessary to introduce small-scale RES. The development of small-scale RES is closely related to the development of legislative acts and mechanisms, as well as to the use of energy-efficient and energy-saving technologies.

According to the above, this thesis is aimed at an integrated approach to studying the development of RES, in particular solar energy, and increasing the efficiency of renewable energy complexes for power supply to low-power consumers.

**Goal of the work**— research and development of an integrated approach to the development and improvement of the efficiency of low-power renewable energy sources.

**Object and subject of research.** The object of the study is a solar installation with photovoltaic panels, the choice of which is determined by the following factors:

- a promising opportunity to integrate solar photovoltaic panels (solar PV panels) into the power supply of households, small and medium-sized businesses, and the development of rooftop solar power plants;
- relatively low cost, accessibility, ease of assembly, operation and maintenance, autonomy;
- environmental friendliness for the environment;
- the possibility of implementation in the heat supply of rural households.

The subject of the research is the study of the energy characteristics of a solar installation using innovative prototypes to improve the efficiency of operating parameters.

**Research objectives.** To achieve the goal, the following tasks were completed:

- analysis of the current state of solar energy in the world and in Kazakhstan;
- analysis of state policy in the field of solar energy in the world and in Kazakhstan;
- analysis of existing low-power solar converters;
- study of solar panels parameters;
- development of a model to increase the efficiency of a solar installation;
- assessment of the area under study for the risk of surge voltages;
- development and research of a prototype device for protecting the inverter system of a solar installation;
- development of recommendations based on the results obtained.

**Research methods.** This thesis uses analytical research methods in combination with an assessment method to examine the current situation, driving mechanisms and incentives in solar energy policy, as well as future development prospects in Kazakhstan and the top 5 countries. The study is based on data and information collected from both peer-reviewed literature and government agency reports that provide up-to-date analysis of solar energy.

To carry out technical tasks, to increase the efficiency of solar technology, experimental and quantitative research methods were used, based on data processing in the software environments PVsyst, MathCAD, Excel and Microsoft Visio using tools for writing macros and plotting graphs. The AutoCAD 2022 software environment was used to create the drawings.

These methods make it possible to determine the concept for the development of solar energy in Kazakhstan for low-power consumers.

**The scientific novelty of the work and the main provisions submitted for defense:**

1. Development of a device model that allows increasing the efficiency of a low-power solar installation;
2. Development of a prototype device for protecting solar inverter system;
3. Development of recommendations for the deployment of small-scale solar energy.

**Theoretical and practical significance of the research** lies in the possibility of using scientific and practical research results in the deployment of small-scale RES and increasing the efficiency of solar technology. The proposed technical solutions were used in the manufacture of a prototype solar installation with photovoltaic panels at the laboratories of the Department of Energy at KazNRTU named after K.I. Satpayeva.

The practical significance of the work is confirmed by the act of introduction into the educational process of the Department of Electrical Power Engineering of the Taraz Regional University named after M.Kh. Dulati. The results of research and development are used in laboratory classes in the discipline «Relay protection and automation of electrical power systems» for EP: 6B07113 – «Electromechanics» and 6B07114 – «Power supply of industrial enterprises and civil facilities» in the direction of training 6B071-Engineering and engineering.

**Connection of work with the plan of state scientific programs.** Scientific research on the topic of thesis was carried out in accordance with the Department's plans of the research work at KazNRTU named after K.I. Satpayev within the framework of a state educational grant for doctoral studies.

**Personal contribution of the author.** All results of the thesis research were obtained by the author himself. The purpose of the study, tasks to achieve, analysis of research methods and results of scientific research were carried out by author under the guidance of local and foreign scientific supervisors. The results of other researchers used in the study were indicated by references to the relevant literature.

**The validity and reliability of scientific statements, conclusions and recommendations are confirmed** in publications recommended by the Committee for Quality Assurance in the Sphere of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Committee for Quality Assurance in the Field of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan); testing in domestic and international scientific conferences; innovative patents of the Republic of Kazakhstan; experimental data confirming the performance of the technical solutions of the prototype.

**Approbation of work.** The results of the work were reported: at the 15th International Symposium of Energy Innovation, February 14-16, 2018, Graz, Austria; at the International Satpayev Readings «Innovative solutions to traditional problems: engineering and technology», April 12, 2018, Almaty, Kazakhstan; at the 11th International Energy Conference IEWT 2019 «Freedom, equality, democracy: good or chaos for energy markets?», February 13-15, 2019, Vienna, Austria; at the III International Scientific and Practical Conference «Science and Education in the Modern World: Challenges of the 21st Century», July 10-12, 2019, Nur-Sultan, Kazakhstan; as well as at scientific seminars of the Department of Energy of KazNRTU named after K.I. Satpayeva.

**Publications.** On the topic of the thesis 13 works were published: 2 articles in journals included in the Scopus database, 4 articles in local scientific journals that are recommended by Committee for Quality Assurance in the Field of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, 4 publications in International conferences and symposiums, 3 patents of the RK.

1. Development of integrated solutions for the decentralization of electricity supply to power-hungry regions. The Electricity Journal, Vol.35, No.4, 2022. ISSN: 1040- 6190. <https://doi.org/10.1016/j.tej.2022.107108>

2. A Review on Solar Energy Policy and Current Status: Top 5 Countries and Kazakhstan. Energies (MDPI), 16(11), 4370, 2023. ISSN: 1996-1073. <https://doi.org/10.3390/en16114370>

3. Analysis of the use of a solar collector for heat supply to a private residential building. Bulletin of KazNRTU, No. 4 (134), 2019, p. 160-164. ISSN 1680-9211.

4. Methods for cleaning photovoltaic panels. Bulletin of KazNRTU, No. 3 (139), 2020, p. 283-287. ISSN 1680-9211.

5. Review of solar energy in Germany and Kazakhstan: policies, current status and prospects. Bulletin of KSTU, Proceedings of the University No. 3 (92), 2023, p. 414-420. ISSN 1680-9211.

**Structure and scope of thesis.** The thesis consists of an introduction, 5 sections and a conclusion, contains 119 pages of typewritten text, 63 figures, 18 tables, 8 appendices and a list of references of 139 titles.