ANNOTATION

of the dissertation work of Khabdullina Guldana Abdukhalykovna on the topic: "Development of a micro-power plants based on renewable energy sources for supplying energy to decentralized areas", submitted for the degree of Doctor of Philosophy (PhD) in the educational program 8D07101 – "Electric Power Engineering".

The development of micro-power plants based on renewable energy sources (RES) for decentralized areas is currently of particular relevance, since many remote and underdeveloped regions of the world still lack access to reliable and affordable energy supply.

The use of renewable energy sources such as solar, wind, hydropower, and biomass can provide sustainable solutions to meet the energy needs of these regions, while also contributing to climate change mitigation and the reduction of greenhouse gas emissions.

In addition, the development of RES-based micro-power plants can stimulate local economic growth, create jobs, and improve the quality of life of communities living in remote and underdeveloped areas.

Thus, the development of a micro-energy complex based on renewable energy sources for decentralized territories is **relevant** for solving the problem of energy poverty, reducing greenhouse gas emissions, promoting sustainable development and improving the well-being of communities living in remote and underdeveloped regions.

Purpose of the study:

The purpose of the study is to develop scientific and theoretical foundations for the effective transformation of renewable energy sources, the use of a microelectric complex based on renewable energy sources for decentralized territories, to identify and evaluate the feasibility of such a system in providing reliable and affordable energy for remote regions.

In particular, research in this area should focus on the following tasks::

- 1. Development of a multi-criteria methodology for evaluating the efficiency of autonomous energy systems based on renewable energy sources, using a hierarchical structure of indicators and an aggregated utility function.
2. Construction and verification of mathematical models for energy generation from solar, wind, and biomass sources, taking into account the climatic, resource, and territorial characteristics of the Republic of Kazakhstan.
3. Development of a combined stochastic renewable energy model (CSM-RES) that integrates various types of generation for calculating the energy and economic performance of autonomous systems.
4. Development of a multi-criteria optimization methodology for RES system configurations based on the CSM-RES, including the formation of a system of criteria using the TOPSIS method and scenario analysis.
5. Creation of a software package that provides automation of calculations, scenario analysis, multi-criteria decision-making, and visualization of results, with the possibility of practical application in design and educational activities.

6. Development and proposal of a vacuum-dynamic power amplifier as a new element that increases the stability and reliability of autonomous energy systems under fluctuations in renewable energy generation.

The implementation of these tasks makes it possible to gain a deeper understanding of the technical, economic, and social feasibility of RES-based micro-power plants for decentralized areas and to contribute to the development of sustainable energy systems.

The objects of research are a hybrid energy system with renewable energy sources.

The subject of the research includes methods, algorithms, software tools, and technical devices for energy generation from renewable sources for decentralized areas.

Research methods. The dissertation employs methods of system analysis and information processing, methods for selection and verification of micro-power plants, simulation modeling methods, and mathematical modeling techniques.

The scientific novelty of the research.

The results submitted for defense are based on computational and theoretical studies and summarize the author's research aimed at improving the efficiency of power supply in decentralized areas through the use of renewable energy sources. The scientific novelty of the obtained results is as follows:

1. For the first time under the conditions of remote regions of Kazakhstan, an integrated methodology for modeling and optimizing configurations of autonomous RES-based energy systems has been developed, combining stochastic modeling, multi-criteria analysis, and software implementation.
2. Adapted mathematical models of solar, wind, and biomass generation have been developed, taking into account the climatic and infrastructural characteristics of Kazakhstan, and a combined stochastic renewable energy model has been proposed to assess the energy and economic performance of autonomous systems.
3. A methodology for multi-criteria optimization of RES system configurations and a system of criteria based on the integration of the CSM-RES and the TOPSIS method has been developed, ensuring the selection of optimal solutions under conditions of uncertainty and multidimensional requirements.
4. A specialized software package has been created that ensures automation of calculations, visualization of results, and analysis of system stability. In addition, a new engineering element—a vacuum-dynamic power amplifier—has been developed to enhance the stability of autonomous RES-based energy systems.

Scientists: D.Blumberga, Anders N. Anderson, I. Pakere, T. Cho, Ya-Jun Leng, Huan Zhang, Mohammed Hammam Mohammed Al-Madani, Fishburn P.C., Elias have made a great contribution to solving various aspects of the methodology for assessing the effectiveness of involving renewable energy sources in electricity supply in decentralized areas based on the principles and methods of a systematic approach. M. Salilih, Alexandra Calvén, Nurul Nadia Ibrahim, Sikandar Ali Qalati, Keeney R.L., Raiffa H., B. Paris, L. Li, U. Jamil, T. Hickey, Pratt J.W., Tleuov A. H., Latif Bektenov, Baitanaeva B.A., Sarsenbaev E. A, Khabdullina Z.K., etc.

Despite the significant number of works in this field, Methods for assessing the effectiveness of involving renewable energy sources in electricity supply in decentralized areas based on the principles and methods of a systematic approach and their practical implementation have not yet been adequately developed.

The theoretical significance of the results lies in the advancement of scientific understanding of renewable energy modeling methods for decentralized areas, taking into account the climatic factors of Kazakhstan, such as sharp temperature fluctuations, snow cover, dust loads, and high wind turbulence. The proposed models of solar, wind, and biomass generation expand the theoretical basis for studying energy conversion processes under regional conditions and enable the formation of reliable scenario sets.

The practical significance consists in the development and validation of a comprehensive methodology for evaluating and selecting optimal configurations of autonomous RES-based energy systems for decentralized areas. The developed software package can be used in design organizations, regional authorities, and educational institutions for the practical implementation of sustainable energy solutions. The developed vacuum-dynamic power amplifier, when widely implemented, makes it possible to significantly reduce electricity and fuel consumption; calculations indicate low specific costs for the generation of 1 kW of energy

Main Provisions Submitted for Defense

1. A stochastic RES modeling methodology including adapted models of solar, wind, and biomass generation for decentralized areas of Kazakhstan, ensuring the formation of reliable scenario sets.
2. A methodology for multi-criteria optimization of energy system configurations based on the integration of a combined stochastic RES model and the TOPSIS algorithm, taking into account energy, economic, environmental, and social factors.
3. An RES-based micro-power plant developed for the village of Stepnoye, Kostanay region of the Republic of Kazakhstan, implemented using a software package integrated with NASA POWER climate databases and local meteorological data, providing automated scenario analysis and visualization of results.
4. A new element of autonomous energy systems—the vacuum-dynamic power amplifier—which enables smoothing of generation fluctuations and enhances the stability of energy supply under variability of renewable energy resources.

The degree of trust and the results of the approbation. The main results of the dissertation work were presented and discussed at international and foreign scientific conferences, scientific seminars.:

1.Хабдуллина Г. А. , «Критерии эффективности использования возобновляемых источников энергии». // Материалы Международной (заочной) научно-практической конференции. НАУКА И ОБРАЗОВАНИЕ: ПРОБЛЕМЫ И ПЕРСПЕКТИВЫ (SCIENCE AND EDUCATION: PROBLEMS AND PROSPECTS, 31 октября 2022, г.Прага, Чехия, С. 43-38.

2.Хабдуллина Г. А., Глущенко Т.И., Бижанов Н.У., «АВТОНОМДЫ ЭНЕРГИЯМЕН ЖАБДЫҚТАУ ЖҮЙЕЛЕРІ ҮШІН БИОМАССА

ЭНЕРГИЯСЫН МОДЕЛЬДЕУ». // Материалы Международной научно-практической интернет-конференции «ТЕНДЕНЦИИ И ПЕРСПЕКТИВЫ РАЗВИТИЯ НАУКИ И ОБРАЗОВАНИЯ В УСЛОВИЯХ ГЛОБАЛИЗАЦИИ» 31 февраля 2023 года (Вып. 90), 31 января 2023 г. г. Переяслав, Украина, с. 231-235.

Personal contribution of the researcher. The author independently carried out all stages of the research, developed methodologies and mathematical models, created a software package for automation of calculations and scenario analysis, developed an RES-based micro-power plant for decentralized areas, and designed a vacuum-dynamic power amplifier. Calculations were performed, results were analyzed, and conclusions were formulated.

Publication of the main results of the dissertation research.

On the topic of the dissertation, 3 copyright certificates, 1 utility model patent were obtained and 6 papers were published, including 1 articles in publications indexed by Scopus and Web of Science and 3 articles published in journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Education and Science of the Republic of Kazakhstan, and 1 monograph and a textbook have also been published:

1. Г.А. Хабдуллина, Т.И.Глущенко, Т.В.Бедыч, «Дәстүрлі емес және жаңартылатын энергетиканың теориялық негіздері», Авторлық құқықпен қорғалатын объектілерге құқықтардың мемлекеттік тізімге мәліметтерді енгізу туралы куәлік 2021 жылғы «22» қазан №21096, Нұр-Сұлтан қ.

2. Г.А. Хабдуллина , Хабдуллин А.Б., Глущенко Т.И., программа для ЭВМ «Вовлечение возобнавляемых источников энергии в системы электроснабжения», Свидетельство о внесении сведений в государственный реестр прав на объекты, охраняемые авторским правом №39752 от «19» октября 2023 года, г. Астана

3. Г.А. Хабдуллина, Т.И.Глущенко, Монография «Применение возобновляе-мых источников энергии для повышения эффективности электроснабжения социальных объектов», Свидетельство о внесении сведений в государственный реестр прав на объекты, охраняемые авторским правом №26567 от «27» мая 2022 года, г. Нур-Султан

4. Г.А. Хабдуллина , Т.И. Глущенко, А.Б. Хабдуллин, «ҚАЗАҚСТАНДАҒЫ ЭНЕРГЕТИКА СЕКТОРЫНЫҢ ЖАЙ-КҮЙІ», Торайғыров университетінің ХАБАРШЫСЫ. Энергетикалық сериясы. Павлодар, 2022 №2, 334-346 б., https://doi.org 10.48081/WWGA7172

5.Г.А. Хабдуллина , Т.И. Глущенко, А.Б. Хабдуллин, «РУДНЫЙ ҚАЛАСЫНЫҢ КҮН ЖӘНЕ ЖЕЛ ЭНЕРГИЯСЫНЫҢ ӘЛЕУЕТІН БАҒАЛАУ ҮШІН МАТЕМАТИКАЛЫҚ МОДЕЛЬДЕРДІ ӘЗІРЛЕУ», Алматы энергетика және байланыс университетінің ХАБАРШЫСЫ, Алматы, 2022 №4 (59) 6-17 б.

6. Г.А. Хабдуллина, А. Б. Хабдуллин, Т. И. Глущенко, А. Б.Тәңірберген, А. К. Жумадирова, «РАЗРАБОТКА И ИССЛЕДОВАНИЕ ВАКУУМНОДИНАМИЧЕСКОГО УСИЛИТЕЛЯ МОЩНОСТИ», Вестник ПГУ. Энергетическая серия. Павлодар, 2023 №1, с.323-334

7. Г.А. Хабдуллина, Т.И.Глущенко, Монография «Применение возобновляе-мых источников энергии для повышения эффективности электроснабжения социальных объектов», Костанай, КРУ им. А. Байтурсынова, 2022 - 96 с., ISBN 978-601-7481-37-7

8. Г.А. Хабдуллина, Т.И.Глущенко, Т.В. Бедыч, оқу құралы «Дәстүрлі емес және жаңартылатын энергетиканың теориялық негіздері», Алматы: Эверо, 2022 – 168 б. ISBN 978-601-352-731-4

9. Guldana KHABDULLINA, Dace PAULE, Ieva PAKERE, Asset KHABDULLIN, Dagnija BLUMBERGA, «Boosting of Dissipated Renewable Energy Systems Towards Sustainability in Kazakhstan», Environmental and Climate Technologies, 2024, vol. 28, no. 1, pp. 540–555 https://doi.org/10.2478/rtuect-2024-0042.

10. Хабдуллина Гульдана Абдухалыковна, Хабдуллин Асет Бакирович, Глущенко Татьяна Ивановна, Патент №9818 на полезную модель Вакуумды-динамикалық қуат күшейткіші , от 22.11.2024 Астана

The structure and scope of the thesis. The dissertation consists of an introduction, five chapters, a conclusion, a list of references comprising 103 sources, and three appendices. The total volume of the work is 154 pages and includes 31 figures and 24 tables.