

ANNOTATION

from a thesis for a degree of Doctor of Philosophy (PhD)

6D071200 - Mechanical Engineering

DYUSSEBAYEV ILYAS MURZAKHANOVICH

DEVELOPMENT AND RESEARCH OF FIXED VERTICAL AXIS WIND POWER PLANT DESIGNS TO IMPROVE PRODUCTION TECHNOLOGY

Relevance. Wind energy has many benefits, which explains why it is one of the world's fastest growing energy sectors.

Wind is a clean source of renewable energy that does not pollute the air like power plants that burn fossil fuels such as coal or natural gas, which emit particulate matter, nitrogen oxides and sulfur dioxide, causing human health problems and economic damage. Wind power plants do not produce emissions into the atmosphere that cause acid rain, smog or greenhouse gases. And since wind is cost-effective and has no price, operating costs after installing a wind power plant are practically zero. Mass production and technological advances are making wind turbines cheaper, and many countries around the world are offering tax breaks to encourage wind power development.

The wind power industry is experiencing an unprecedented rise. Thanks to worldwide efforts to combat climate change, such as the Paris Agreement, renewable energy is booming, with wind power leading the way. From 2000 to 2015, cumulative wind power worldwide increased from 17,000 megawatts to over 430,000 megawatts. In 2015, China also overtook the EU in the number of installed wind turbines and continues to lead in installation.

According to experts in this area, if such growth rates continue, by 2050, one third of the world's electricity needs will be satisfied by wind energy.

Wind power plants, existing in the US and Europe, are of high capacity and production cost. Most regions of Kazakhstan are characterized by average annual wind speeds of up to 5 m/s. The existing wind turbines are designed for more powerful wind speeds (8-10 m/s) and are intended for use in coastal areas.

There are also a number of problems in wind power plants. Wind power still has to compete with traditional sources of power generation in terms of cost. Even though the cost of wind power has dropped dramatically over the past few decades, wind projects must be able to compete economically with the cheapest source of electricity, and in some places there may not be enough winds to be cost competitive.

Good onshore wind farms are often located in remote locations away from cities where electricity is needed.

Wind resource development may not be the most profitable land use. Land suitable for the installation of wind turbines must compete with alternative land uses that may be more valuable than electricity generation.

Turbines can cause noise and aesthetic pollution. Although wind farms have a relatively small environmental impact compared to conventional power plants, there are concerns about the noise produced by the turbine blades and the visual impact on the landscape.

The existing methods for designing wind turbines are mainly focused on high-capacity horizontal-type installations.

In the context of high energy consumption in Kazakhstan and involvement in the global processes of dynamic development of renewable energy sources (RES), the field of wind energy is becoming extremely relevant. In this case, both a number of advantages, including the competitiveness of this type of energy production, and the great potential of Kazakhstan in development thereof in terms of the geographical position of the country are of certain importance.

In accordance with the long-term National Program for the Development of Wind Energy in the Republic of Kazakhstan up until 2024, goals were set for using the wind energy potential of Kazakhstan to generate electricity in the amount of 900 million kWh per year by 2015 and 5 billion kWh by 2024 in the light of the tasks set in the Concept of the transition of the Republic of Kazakhstan to long-term sustainable development and the long-term Strategy for industrial and innovative development of the Republic of Kazakhstan to preserve natural resources and the environment[2]. The need to introduce wind turbines in the Republic of Kazakhstan is due to the fact that enterprises that have been generating electricity since the times of the USSR are technically outdated, while the construction of new ones required large material costs. And it was also due to the lack of components, that the construction of new energy supply enterprises turned out to be practically impossible [2].

Low power vertical axis installations have received less attention. The choice of schemes and structures of wind power plants operating at low wind speeds has been studied to a limited extent. The relevance of the problem **is in** establishing methods for the synthesis and analysis of the parameters of vertical wind power plants, taking into account low wind speeds, device weight and dimensions.

It should be noted that in the speed range from 2 to 5 m/s, the output power of existing wind turbines **includes** only a small part of the received wind energy. An assumption that when the calculated speed is exceeded leading to artificial lowering of the rotational speed which results in limited use of the wind energy, makes it possible to explain the low coefficient of wind energy utilization (0.41-0.47) of modern wind power plants. In this regard, the **relevance** of this work is beyond doubt and, in scientific terms, deals with the need to develop and unify an approach to a number of low-capacity wind power plants with a vertical axis of rotation, manufacturing technology for the axis and the blade itself.

The thesis work dealing with the development and research of the fixed vertical axis wind power plant designs in order to improve the production technology contains new evidence-based based results of research and technical developments on the creation of an improved wind wheel model, the use of which provides a solution to an important problem of ecological safety of the environment by reducing the impact of toxic components resulting from replacing traditional energy sources.

Goal of the work. Research of fixed vertical axis wind power plant structures, development of design and technological solutions as well as technology for WPP production and construction.

Study objectives:

- analysis of modern achievements in the area of designing machines for wind power plants;
 - to substantiate the need for a methodological approach to the development and creation of vertical-axis wind power plants (VA WPP);
 - to make a detailed VA WPP design model in order to obtain maximum simplicity;
 - to optimize the WPP design in detail in order to obtain maximum energy generation;
 - to develop technological processes for the manufacture of wind power plant components.

The object of the study is low-capacity wind power plants.

The subject of the study is low-capacity wind power plants design methods.

Study methods.

- the results of the study were obtained on the basis of theoretical and practical provisions of the theory of wear; theories of elasticity and plasticity; theory of experiment planning and statistical data processing
- analytical methods involved in functional-structural analysis of applied aerodynamics;
- method for comparing the results of theoretical and experimental studies;
- method of critical evaluation of scientific study results by scientists from near and far abroad.
- experimental studies were carried out in bench conditions on operating equipment using original methods and modern measuring equipment.

Scientific novelty of the study results:

1. 3D models of wind turbines have been developed based on the classification by purpose, the method of using the wind flow, and the variability of the area of the wind receptacle.
2. A theoretical and experimental substantiation was provided for the application of the methodology for calculating hollow semi-cylindrical wings to the calculation of wind power plants in the dynamic synthesis of wind power plants with hollow semi-cylindrical blades
3. The wind flow energy utilization factor at low wind speeds has been developed.

Practical value of the work:

- the developed calculation methods were used in the design of low-capacity wind power plants and the choice of their parameters;
- the proposed designs of wind power plants with additional rotary elements are smaller in weight and dimensions, and have better energy characteristics than the existing ones;
- the study results were used in the practical work of scientific and production associations of the Republic of Kazakhstan;
- the study results were used in the educational process and master's theses.

The following provisions are submitted for defense:

1. Wind power plants 3D model which allows the synthesis of the most rational schemes of WPPs.
2. Technique for synthesizing wind power plant schemes based on a functional-structural model.
3. Method for lattice blades WPP scheme calculation.

Approbation of the study results.

The main provisions of the thesis were discussed and reported at international conferences and papers recommended by the Committee for Quality Assurance in Education and Science of the Ministry of Education: ISPC «Satpayev Readings» 2019, 2020 - Almaty: Kazakh National Research Technical University named after K.I. Satpayev; XII International Scientific and Practical Conference «Modern Problems of Mechanical Engineering» 2019 Tomsk: TPU, Russia; VIII ISPC «GLOBAL SCIENCE AND INNOVATIONS 2020: CENTRAL ASIA» - Nur-Sultan, 2020, Kazakhstan ISSN 2664-2271; Bulletin of KazATC, 2020. - No. 1 (112) ISSN 1609-1817; INTERNATIONAL SCIENTIFIC JOURNAL «GLOBAL SCIENCE AND INNOVATIONS 2021: CENTRAL ASIA» NUR-SULTAN, KAZAKHSTAN, DECEMBER 2021; Bulletin of the Tomsk Polytechnic University (TPU), 2019 (Russia);

The main scientific results, practical conclusions and recommendations are as follows:

1. The need for a methodological approach to the development and creation of vertical-axis wind power plants (VA WPP) has been substantiated;
2. The detailed VA WPP design model has been examined in order to obtain maximum simplicity;
3. The VA WPP design has been optimized in detail in order to improve the production technology;
4. The technological processes for the manufacture of wind power plant components have been developed.
5. 3D models of wind turbines have been developed based on the classification by purpose, the method of using the wind flow, and the variability of the area of the wind receptacle;
6. A theoretical and experimental substantiation was provided for the application of the methodology for calculating lattice wings to the calculation of wind power plants in the dynamic synthesis of wind power plants with lattice blades;
7. The wind flow energy utilization factor at low wind speeds has been determined.
8. A technique has been developed for mathematical modeling of the plant windwheel, taking into account the influence of changes in wind speed.

Summing up, the characteristics of the thesis work are as follows:

Evaluation of the completeness of the solution of the tasks. The set goal of the work has been achieved, the study tasks have been completely solved, the study results have been brought to implementation.

Recommendations for input data on the specific use of the results have been developed. The results of the work can be recommended for use by engineers

and designers, as well as in the university academic process under engineering and environmental specialties.

Evaluation of the technical and economic efficiency of implementation. Prevention of damage to the ecology of the region due to the introduction of developments on the use of green energy instead of traditional energy sources.

Evaluation of the scientific level of the work performed in comparison with the best achievements in this field. Scientific developments and their novelty have been sufficiently examined in publications of various levels, in master's theses and graduation works, as certified by the relevant documents and enactments.

Publications. Based on the results of the research, 10 scientific articles were published, of which 3 articles were for international conferences within the country, 1 article for a foreign international conference, 4 articles in journals recommended by the the Committee for Quality Assurance in Education and Science of the Ministry of Education of the Ministry of Education of the Republic of Kazakhstan, 2 articles in the SCOPUS database (percentile 43).

Contribution of the author of the thesis work to the preparation of publications

1. **«Methodological basis for the application of wind generators in geology».** NEWS OF THE ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN Satbayev University №5 (455) 2022 г. Almaty. The selection of materials for the review and its writing, the writing of the introduction, methodology and conclusion, the preparation of schedules and their description, the design of the article.

2. **«Determination of Geometric Parameter of Cycloidal Transmission from Contact Strength Condition for Design of Heavy Loading Mechanisms».** International Conference on Mechanical Engineering and Modern Technologies 2019 (MEMT2019) 28 October 2019 - 1 November 2019, Tomsk, Russian Federation Volume 795. Development of the report plan, selection of materials, writing the main part with discussion of research results.

3. **«Study of Directions of Development for Improving the Design of Wind Power Plants with a Vertical Axis of Rotation of the Wind Wheel».** «Bulletin of KazATC», KazATC named after. M. Tynyshpayev, 2020 Almaty. Search for publications for the review and its writing, writing sections: research methodology, research results, design of schedules, responses to reviewers' comments.

4. **«Агроөнеркәсіптік кешендегі роторының қуаты аз айналу осі вертикаль желэнергетикалық қондырғылардың конструкцияларының сызбасын зерттеу перспективалары мен талдауы».** «Bulletin of KazATC», KazATC named after. M. Tynyshpayev, 2022 Almaty. Writing sections: introduction, research methodology, mathematical processing and discussion of experimental results, article design.

5. **«Жел генераторлары әскери мақсаттағы объектілер үшін баламалы энергия көзі ретінде».** «BULLETIN of the Military Institute of the National Guard of the Republic of Kazakhstan», Military Institute of the National Guard of the Republic of Kazakhstan, 2023 Almaty. Search for publications for the

review and its writing, writing sections: research methodology, research results, design of schedules, responses to reviewers' comments.

6. **«Vertical Axis Wind Power Plant Design Comparisons, Characteristics and Main Types»**. Proceedings of the international conference «Innovative Technologies - Key to the Successful Solution of Fundamental and Applied Problems in the Ore and Oil and Gas Sectors of the Economy of the Republic of Kazakhstan», 2019 - Almaty: Kazakh National Research Technical University named after K.I. Satpayev. ISBN 978-601-323-145-7. Development of the report plan, selection of materials, writing the main part with discussion of research results.

7. **«The state of development of vertical axis wind power plants. XII International scientific and practical conference «Modern Problems of Mechanical Engineering» 2019 Tomsk: TPU, Russia**. Development of an article plan, writing a review, methodology and discussion of results, responses to reviewers' comments.

8. **«Analysis of the Aerodynamic Parameters of Low Capacity Vertical-Axial Wind Power Plants»**. International scientific and practical conference «Satpayev Readings 2020»: the publication contains the conference proceedings. II C21 - Almaty: Kazakh National Research Technical University named after Satpayev, 2020. - 744 p. SBN 978-601-323-209-6. Development of an article plan, writing a review, methodology and discussion of results, responses to reviewers' comments.

9. **«The State of Development of Modern Wind Power Plants and the Issues of Dynamics and Strength Associated with them»**. VIII International scientific and practical conference «GLOBAL SCIENCE AND INNOVATIONS 2020: CENTRAL ASIA», 2020 Nur-Sultan, Kazakhstan ISSN 2664-2271. Development of the report plan, selection of materials, writing the main part with discussion of research results.

10. **«Design, Modeling and Improvement of Savonius Type Vertical-Axial Wind Power Plants of Low Capacity»** International scientific and practical conference «Satpayev Readings 2020»: the publication contains the conference proceedings. II C21 - Almaty: Kazakh National Research Technical University named after Satpayev, 2020. - 744 p. SBN 978-601-323-209-6. Development of the report plan, selection of materials, writing the main part with discussion of research results.

The structure and scope of the thesis work. The thesis work consists of three chapters, contains a list of 100 references, is presented on 100 pages, contains 42 figures, 7 tables.