

ABSTRACT

of a dissertation for the degree of Doctor of Philosophy (PhD)
8D07101 – Mechanical Engineering

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INCREASING THE EFFICIENCY OF WIND POWER PLANTS BASED ON THE RESEARCH OF INPUT DESIGN PARAMETERS

Relevance. Currently, there is a global trend towards decentralization of energy. The transition to renewable energy sources is a global trend. The development of this trend is facilitated by the improvement of mechanical engineering technologies, the availability of financial opportunities and various incentive programs, as well as public awareness of environmental issues.

To achieve carbon neutrality, the annual capacity of wind turbines must be increased by 4 times.

The cost of renewable energy technology and energy storage has been falling in recent years. Wind power is a key resource that will help the world find a practical way out of the current situation with the cost of energy generation and transportation. There are literally terawatts of «shovel-ready» projects that would reduce dependence on fossil fuels and unlock huge volumes of investment almost immediately if governments take urgent measures to remove legislative and administrative barriers.

A number of countries have launched policies to develop wind energy, including the introduction and scaling of low-power installations.

In the Address of the President of the Republic of Kazakhstan to the people of Kazakhstan on September 1, 2020, Kassym-Jomart Tokayev announced that by 2030 the indicator of the development of the renewable energy sector should be 15%, by 2050 50%, by 2060 the President sets the goal of achieving carbon neutrality. This instruction to the Government of the Republic of Kazakhstan can be considered one of the principles of the country's new economic course.

Today, when the renewable energy sector has reached the share of electricity generation from renewable energy sources of 3%, serious management and engineering competencies have been developed, sufficient investments have been attracted and large industrial-scale renewable energy facilities have been launched, there are great opportunities for further growth. For the further development of renewable energy in our country, it is necessary to develop new areas, such as energy storage projects, as well as small-scale renewable energy projects.

There is demand and interest of the population (households and legal entities) in small-scale projects in our country. This interest is based on a large share of the population living in the private sector, the desire to reduce and optimize their

electricity costs, to solve problems related to the inaccessibility of public utilities in remote regions, favorable natural and climatic factors, especially in the southern regions of the country.

In this regard, I believe that now the renewable energy sector in Kazakhstan, which has successfully implemented a number of renewable energy projects over the past five years, has prospects for further development and new challenges.

As a result, there is a need to create a wind turbine that will be maximally adapted to the geographical features of Kazakhstan. When creating a wind turbine, it must be provided with a wind wheel (WW) design that produces maximum values for rotation frequency and developed power.

Purpose of the work. The aim of the dissertation is to create a prototype of a low-power wind power plant with increased efficiency and resistance to hurricane gusts of wind.

Research objectives:

- monitor existing wind turbine designs, taking into account the identification of deficiencies;
- develop and manufacture a test bench for studying the design parameters of a wind wheel while ensuring a constant air flow speed;
- identify the optimal design parameters of a wind wheel based on experimental studies of laboratory models of wind wheels and minimization of power losses;
- develop a method for determining the efficiency of a wind turbine;
- develop a new design of a storm protection mechanism;
- develop a prototype of a low-power wind turbine using the research results.

Object of research: Low-power horizontal-axis wind turbines.

Subject of research: power head, including a wind wheel with a system of levers for regulating the rotation speed.

Research methods. The results of the research were obtained on the basis of theoretical and practical provisions of mechanical engineering technology. The main methods from general scientific methods were applied: experiment, measurement, analysis, generalization. The analysis will be carried out by direct selection of input design parameters, detection of their properties by conducting simple measurements using the ranking method (selection of the main factors and exclusion of secondary ones). MS Excel and Solid Works software package were used in the study of the wind wheel and storm protection mechanism.

Scientific novelty of the research results:

1. The optimal design parameters of wind wheels have been determined, which are adopted on the basis of minimizing losses in rotation speed, torque and power, which has increased the wind energy utilization factor by 16,8%.
2. A scientifically sound design of a wind wheel with storm protection has been developed;

3. A mathematical model (formula) for selecting the design parameters of a wind wheel (number of blades, their installation angle, blade shape, relative area and presence of a fairing) has been developed; the factor has been increased by 15,2%.

4. A method for calculating the speed control of the wind turbine and storm protection with blade rotation by means of a screen-lever mechanism has been developed.

5. A method for calculating the speed control of the wind turbine and storm protection by moving the wind wheel out of the wind has been developed.

Practical value of the work:

– the developed calculation methods were used in the design of a prototype of a low-power wind power plant;

– the results of the study and the prototype of the wind power plant were used in the practice of scientific and production associations and industrial enterprises of the Republic of Kazakhstan;

The following is submitted for defense:

1. Methodology for identifying optimal design parameters of a wind wheel based on experimental and theoretical studies.

2. New prototype of a wind power plant with a capacity of 0.5 kW and increased efficiency, operating at an air flow speed of 3 m/s.

Testing the research results. The main provisions of the dissertation were discussed and reported at international conferences and works recommended by the Committee for Control in the Sphere of Education of the Ministry of Education and Science of the Republic of Kazakhstan: International Scientific Conference 2021 Kazan (Russian Federation), International Scientific Conference «XXII Satpayev Readings» 2022.

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

1. The necessity of a methodological approach to the development and creation of low-power wind turbines is substantiated;

2. A methodology has been developed for studying the dependence of optimal factors of blade installation angle and the number of blades on a laboratory model of a low-power wind turbine using a wind tunnel.

3. A methodology has been developed for studying the dependence of the blade shape and their number on a laboratory model of a low-power wind turbine using a wind tunnel.

4. The use of autonomous regulation of the rotation frequency of the wind wheel and storm protection is substantiated theoretically and experimentally.

5. A method of mathematical modeling based on 3D models of wind wheels with different ratios of blade and fairing lengths has been developed.

In general, summing up, the following characteristics of the dissertation work can be given:

Evaluation of the completeness of the solution of the assigned tasks. The stated goal of the work has been achieved, the research tasks have been fully solved, and the research results have been brought to implementation.

Development of recommendations of initial data for the specific use of the results. The results of the work can be recommended for use by designers and planners, as well as in the educational process of universities in engineering specialties.

Evaluation of technical and economic efficiency of implementation. Development of export potential of metallurgical enterprises exporting products to the countries of the European Union. Reduction of environmental emissions from the implementation of developments in the use of green energy to replace traditional thermal 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 tested in publications of various levels, by scientific organizations and enterprises, which is confirmed by relevant documents and Acts.

Publications. Based on the materials of the dissertation, 8 printed works were published: of which 1 article in a foreign publication from the SCOPUS database (percentile 38), 5 in publications recommended by the Committee for Control in the Sphere of Education of the Ministry of Education and Science of the Republic of Kazakhstan and 2 works in the materials of International Conferences.

Contribution of the candidate to the preparation of publications

1. **«Determination of orientation parameters and automatic wind wheel speed control».** Journal of Applied Engineering Science (JAES) Vol.22, No. 1, 2024. Belgrade, Serbia. Writing sections: introduction, research methodology, mathematical processing and discussion of experimental results, article design, responses to reviewers' comments.

2. **Choosing the optimal variant of the shape and relative area of the blade of the wind wheel of a low-power wind power plant.** Republican scientific and technical journal «University of Enbekteri - University Works» Karaganda Technical University named after Abylkas Saginov, 2023, No. 2 (91). Search for publications for the review and its writing, writing sections: research methodology, research results, design of graphs, responses to reviewers' comments.

3. **Research and Justification of the Parameters of the Wind Wheel of a Low-power Wind Power Plant for Various Purposes.** Republican scientific and technical journal «University of Enbekteri - University Works» of NAO «Karaganda Technical University named after Abylkas Saginov», 2023, No. 3 (92). Search for publications for the review and its writing, writing sections: research methodology, research results, design of graphs, responses to reviewers' comments.

4. **Calculation of the mechanism of autonomous control of the wind wheel rotation speed and storm protection.** Scientific journal of Toraigyrov University «Science and Technology of Kazakhstan», 2023. No. 4. Search for publications for

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

5. Development of a methodology for calculating the speed of rotation of a wind wheel using a storm protection mechanism. Scientific journal of Toraigyrov University «Science and Technology of Kazakhstan», 2024. No. 1. Development of a method for calculating the rotation frequency of a wind wheel using a storm protection mechanism. Selection of materials for the review and its writing, writing the introduction, methodology and conclusion, preparation of graphs and their description, design of the article.

6. High-efficiency low-capacity wind turbine with storm protection. Scientific journal. Bulletin of Toraigyrov University, 2022. No. 3. Search for publications for the review and its writing, writing sections: research methodology, research results, design of graphs and figures, responses to reviewers' comments.

Structure and volume of the dissertation. The dissertation consists of an introduction, 4 chapters, a conclusion, 7 appendices and a list of references containing 114 titles. The total volume of the dissertation is 130 pages, including 59 figures and 27 tables.