ABSTRACT

of dissertation submitted for the Doctor of Philosophy (PhD) degree in specialty 6D071800- "Electrical power engineering"

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IMPROVING A CLOSED-TYPE WIND POWER PLANT IN A COMPLEX USING OF THE SOLAR ENERGY

Relevance of the work.

The Republic of Kazakhstan has a law “On supporting the use of renewable energy sources”, which supports the use of renewable energy sources and the fulfillment of our country's international obligations to reduce polluting waste. The purpose of this law is to initiate certain incentives for the generation of electrical energy using renewable energy sources to narrow the impact of the production of electrical energy on nature and expand the scope of application of renewable energy sources in the generation of electrical energy. According to this law, to support devices using renewable energy sources of low power, and to provide electricity to objects with less favorable natural or other conditions to increase the use of these devices, special tariffs are established in correlation with the nominal generated energy of the devices.

The prospects for the development of wind energy and solar energy in our country are due to the high potential of wind and solar energy, as well as the development strategy of our country "Kazakhstan - 2050", which considers the need for the transition to the third industrial revolution and to the "green economy". The development of this strategy is associated with the growing need of the world economy for clean energy, with a growing population, with limited reserves of traditional fossil resources, with ensuring energy security, with protecting the environment from pollution by organic fuel waste during its combustion, preserving the resource base of energy reserves for the country's prospects ...

Our republic is ranked ninth in the world in terms of the available territory and has an average population density of 6.7 people / km^2. In this regard, for residents of remote areas, there is the issue of providing electricity due to the increased cost of transit of the traditional type of energy and the high cost of construction, as well as the operation of overhead power transmission lines (PTL). Stand-alone renewable energy converters such as wind turbines and photovoltaic converters (PV) are needed for such areas.

The implementation of the results of scientific research on the use of wind energy is mainly carried out in the territories of our country with good wind conditions, where wind speeds in the range of 9-12 m / s are provided, which ensures the optimal operation of these wind power plants. On the other hand, most of the territory of our country has an average annual wind speed of less than 6 m /

s. In the central part of the country, in January, the average monthly wind speed is in the region of 4-6 m / s, and in the southern part of the country it is in the region of 2-4 m / s. The main consumers of electrical energy are located in such areas. In this regard, new technical solutions are needed to ensure effective conversion of wind energy into electrical energy at low average annual wind speeds in the area, which makes it urgent to develop and create a wind power plant that is able to meet the above conditions.

Theoretical and practical significance of the research.

The significance of the research is the possibility of using the scientific results of the dissertation in the production of closed-type wind power plants (CTWPP) for local power supply in combination with the use of wind and solar energies. The proposed technical solutions were used in the manufacture of a laboratory sample of a closed-type wind power plant with a horizontal axis of rotation of the wind turbine in the laboratory at the Department of Energy of KazNRTU named after K.I. Satpayev.

The practical significance of the work is confirmed by the act of introducing into the educational process of the Department of Energy of KazNRTU named after K.I. Satpayev. The results of the work are used in the classes of disciplines: "Renewable energy sources", "Alternative energy", "New and renewable energy sources", "Renewable energy" for specialties 5B071800, 6M071800 - "Electricity" (Appendix A).

An act of introduction into the educational process of the Al-Farabi Kazakh National University was received at the Department of Plasma Physics, Nanotechnology and Computer Physics of the Faculty of Physics and Technology. The research results are used in lectures and practical classes in the following disciplines: "Alternative energy", "Non-traditional and renewable sources of electricity", "Wind energy", read for the specialty 5B071800 - "Power engineering" (Appendix B).

The purpose of the work is to study and improve a closed-type wind power plant with a horizontal axis of rotation of a wind turbine for local power supply in combination with the use of solar energy.

Object and subject of research.

As an object of research, a closed-type wind power plant with a horizontal axis of rotation of a low-power wind turbine for local power supply was selected and this is due to the following indicators:

- the potential for future operation of closed-type wind turbines with a horizontal axis of rotation of the wind turbine at different wind flow rates, especially at low wind speeds, which is typical for most of the territory of Kazakhstan;
- a fairly high utilization rate of wind energy in comparison with open-type wind power plants, especially at low wind flow rates;
- accessibility for consumers, such as tourist recreation areas, farms, pumping stations, etc., located far from the unified electrical network;

- environmentally friendly installation in comparison with various power plants of high power, which require the acquisition of land and produce various pollutants.

The subject of this research is the study of processes in a closed-type wind power plant when converting wind energy into electrical energy for further improvement of the installation.

Connection of work with the plan of state scientific programs.

Scientific research on the topic of the dissertation was carried out in accordance with the plans of the research work of the Department of Energy of the KazNRTU named after K.I. Satpayev, where the dissertation author studied in doctoral studies and was assigned as an applicant. The research was carried out within the framework of the theme "Unified wind power plant (WPP) for local energy supply" in 2014-2017, state registration number 0116RK00433.

Research objectives.

To achieve the goal, the following tasks were set:

- development and research of a computer model of a closed-type wind power plant at different wind speeds;
- development of an efficient closed-type wind power plant for converting wind energy into electrical energy;
- development of an effective solar panel solar tracking system in a combined system for converting wind and solar energy;
- study of the work of a prototype of a wind power plant at different loads and speeds of the wind flow;
- study of the operation of a prototype solar power plant with a tracking system for the sun.

Research methods.

To solve the set tasks in the dissertation, the provisions of the theoretical foundations of aerodynamics and design of wind turbines were applied. Proven methods for determining the parameters of a wind power plant with a horizontal axis of rotation of a wind turbine were used, which are used by domestic and foreign scientists. A simulation of a wind power plant in the engineering analysis software COMSOL Multiphysics 5.0, SolidWorks 2016 with the CFD (Calculation Fluid Dynamics) component has been performed. Autodesk Inventor Professional 2015 software was used to build parts of the wind turbine.

The validity and reliability of scientific provisions, conclusions and recommendations are confirmed by publications in publications recommended by the Committee for Control in the Sphere of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan (MES RK); approbation in domestic and foreign international scientific conferences and forums, as well as in the World Congress of Engineers and Scientists "Future Energy: Innovative Scenarios and Methods for Their Implementation" WSEC-2017, which was held as part of the World Exhibition "EXPO-2017"; mathematical validity, experimental data obtained during experiments, which confirm the performance of technical solutions when used in prototypes.

Scientific novelty of the work. The scientific novelty of the work is that the work proposes and substantiates the energetically efficient structural elements of a closed-type wind power plant, obtained by engineering analysis of a computer model and experimental research.

The main key points for the defense.

The following basic key points are put forward for defense:

- improved and justified structural elements of the wind power plant and the roof of the building, increasing the efficiency of wind energy use;

- an efficient closed-type wind power plant with a horizontal axis of rotation of a wind turbine with improved aerodynamic characteristics confirmed by experimental research;

- a combined system for the integrated conversion of wind and solar energy with an effective solar tracking system, which increases the reliability of power supply to autonomous energy consumers.

Approbation of work.

The main results of the work were reported: at the scientific seminars of the Department of Energy of the KazNRTU named after K.I. Satpayev; at the International Forum "Engineering Education and Science in the XXI Century: Problems and Prospects", dedicated to the 80th anniversary of KazNTU named after K.I. Satpayev, October 22-24, 2014, Almaty, Republic of Kazakhstan; at the International Satpayev Readings "The role and place of young scientists in the implementation of the new economic policy of Kazakhstan", April 12, 2015, Almaty, Republic of Kazakhstan; at the VI International Scientific and Practical Conference "The latest technologies for the development of hydrocarbon deposits and ensuring the safety of ecosystems of the Caspian shelf", September 7, 2015, Astrakhan, Russian Federation; at the International Satpayev Readings "Competitiveness of Technical Science and Education", April 12, 2016, Almaty, Republic of Kazakhstan; at the World Congress of Engineers and Scientists "Future Energy: Innovative Scenarios and Methods for Their Implementation" WSEC-2017, June 19-20, 2017, Astana, Kazakhstan.

Publications.

On the topic of the dissertation, 16 publications were published, of which 3 articles were published in publications recommended by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 2 articles - in journals included in the Scopus database, 8 publications in International conferences and forums. There are 3 patents for a useful model.

The structure and scope of the thesis.

The thesis consists of an introduction, 4 chapters and a conclusion, contains 118 typewritten pages, 87 figures, 7 tables, 16 appendices and a list of used literature of 122 titles.

The main content of the work

The introduction shows the relevance of scientific work and the significance of the study. The goal and objectives of scientific research are set. The scientific novelty and the provisions to be defended are presented. The practical significance of the results and the methods of the research are shown. Publications, approbation, as well as the relationship of work with the plan of state scientific programs are covered.

The first chapter of the dissertation is devoted to a review of the current state of development of renewable energy sources in the world, including wind energy and solar energy. The analysis of the developed installations and the prospects for the development of renewable energy are carried out.

The generation of electric energy by modern wind power plants depends on the strength and direction of the wind, which is very volatile. A weak wind (up to 2 m / s) does not provide rotation of a wind turbine, a strong wind (more than 20 m / s) can destroy a wind turbine. Rain and snow, hail cause icing, complicate operation and reduce the overall resource of work. The complexity of installation and maintenance, which is associated with the enormous dimensions of wind turbines, complicates the operation of large installations. All these problems complicate the design of wind turbines, which leads to the high cost of generated electricity.

In connection with the above problems, research, development and improvement of the installation for the efficient conversion of wind and solar energies in a closed-type wind turbine complex for local energy supply is being carried out.

The second chapter describes the study of a closed-type wind turbine model with a horizontal axis of rotation of a wind turbine and analysis of its individual elements, such as a confuser, diffuser and cone.

The design of a closed-type wind turbine was carried out in COMSOL Multiphysics engineering analysis software, which performs calculations using the finite element method. This method is widely used in modeling the processes of diffusion, heat conduction, hydrodynamics, mechanics, and its field expands with an increase in the ability of computer systems.

The finite element method with particles is used to model fluid and gas flows in areas of complex shape, fluid and gas flows with a free surface, spray formation processes, and also solving related problems of hydraulic elasticity.

To simulate the flow, the Navier-Stokes system of differential equations is widely used. The main problems in solving the Navier-Stokes equations are related to differential equations for the laws of conservation of mass and momentum.

The wind turbine design model in the simulation of engineering analysis software should be close to the full-scale model. For this, the model should give the same and converging results in the grids, the grid should be small enough on important areas of the structure to avoid errors in hydrodynamic calculations, the calculation area above the wind turbine model should be high enough to avoid narrowing the air flow.

The closed-type wind turbine design model consists of the following elements:

1. The guide cone, located in the middle of the structure on the same axis as the wind turbine body, directs the air flow to the zone of location of the wind turbine blades;

2. The wind turbine housing, consisting of a front cavity made in the form of a truncated cone, and an expanding rear cavity, which contribute to the acceleration of the wind in the area of location of the wind turbine blades;

The design under consideration contributes to an increase in the speed of the wind flow due to the use of a confuser and a diffuser, which makes it possible to increase the utilization of wind energy and lower the lower threshold of the operation range of the installation.

The analysis revealed an effective version of the design of wind turbines and the roof of the building, where the highest acceleration of the incoming air flow is achieved, as well as recommendations on the shapes and angles of attack of various elements. The cone, diffuser, cone and roof of the building for the effective conversion of wind energy into electrical energy have the following parameters: angle of attack of the confuser $\alpha = 7.970$, angle of attack of the diffuser $\alpha = 32.620$, thickness of the body L = 0.02 m, angle of attack of the cone $\alpha = 26.570$ and angle of attack of the roof of the building 300.

The third chapter discusses the technical solutions of a closed-type wind power installation and a sectional synchronous generator with permanent magnets. According to these technical solutions, patent applications have been filed.

Various systems for tracking the sun of solar panels are considered and the most effective tracking system that is able to work in an integrated system for converting wind and solar energies for reliable energy supply is identified.

The fourth chapter is devoted to experimental studies of closed-type wind turbines in a complex using solar energy. This section describes a prototype wind turbine of a closed type and a solar panel with a tracking system for the sun, as well as appropriate measuring instruments for measuring parameters during testing.

Wind turbine tests were conducted for open and closed type at various wind speeds. As can be seen from the test results, the developed closed-type wind power installation is noticeably more efficient than an open-type wind turbine and earlier begins to generate electrical energy. This indicates that the aerodynamic characteristics of the experimental setup is better, and the moment of inertia of the device is lower. Thus, the efficiency of wind turbines is 17.5% higher than open wind turbines.

According to the test results, the sun tracking system is 41.17% effective compared to the stationary system.

In conclusion, the main results and conclusions on the dissertation are reflected.