ANNOTATION

Dissertations for the degree of doctor of philosophy (PhD)
6D060400-Physics

DYUSEMBAYEVA AINURA NURTAYEVNA

Study of the aerodynamics of a combined wind turbine with a vertical axis of rotation

The relevance of the topic. The potential of renewable energy resources has a special place in Kazakhstan. These include, first of all, wind power, for the development of which it is very important to have reliable information about the wind regime on the territory of the proposed location of wind power plants. It should be noted that wind energy does not pollute the environment and can generate clean, inexhaustible energy on the place.

The potential of renewable energy resources in the country is at a sufficient level. The production of alternative energy in Kazakhstan is about 1% of the total. Since the wind speed is low in most regions of Kazakhstan. The use of currently known wind turbines of low wind speed is economically impractical. And the principles of operation of some wind turbines, including blades in the form of rotating cylinders, are little studied. In this regard, a relevant problem is the creation of combined cylindrical wind turbines with a vertical axis of rotation that work effectively at low wind speeds.

The social need to carry out scientific work is associated with obtaining a source of electricity in economic and household activities. The combined wind turbine studied in the dissertation work can provide electricity to stand-alone institutions, small farms, institutions remotely located from a centralized source of electricity. The economic incentive in the implementation of the thesis is the development of the wind energy market in Kazakhstan.

The purpose of the dissertation is to study the aerodynamic characteristics of a combined wind turbine with a vertical axis of rotation with high energy efficiency.

The objects of research are a laboratory and experimental (prototype) sample of a combined wind turbine with a vertical axis of rotation.

Scientific novelty:

- for the first time, a prototype of a combined wind turbine with a vertical axis of rotation has been developed, which has a high energy output, effectively operating on the basis of the Magnus effect at low wind speeds. The wind turbine starts working at a wind speed of 2.8 m/s;

- an electric generator with rare neodymium magnets has been developed, which, unlike other electric generators, can charge batteries at the required level without requiring lower revolutions and additional gears.

- it is proved that at low wind speeds (from 2.8 m/s) with an increase in the number of constant cylinder revolutions (300 rpm - 700 rpm), the difference between the drag forces increases by 4-5 %;

- it is established that at an air flow velocity of 5 m/s, the angle of inclination of the fixed blade relative to the rotating cylinder reaches $0^0 \leq \alpha \leq 90^0$, the drag force increases to a maximum value of 2.55 N, the lifting force decreases to a minimum value of 1.27 N;

- it is proved that when the angle of inclination of the fixed blade changes relative to the cylinder $90^0 \leq \alpha \leq 180^0$, the lifting force appears, when the air flow changes by an angle of 180^0, the lifting force increases to 2.7 N;

- the obtained universal experimental dependences of the drag and lift coefficients are in satisfactory agreement with the results of mathematical modeling based on the numerical solution of the Navier-Stokes equation using the Ansys Fluent software package;

- it is established that the power generation of the electric generator begins at a wind speed of 2.8 m/s, the rotation speed of the combined wind turbine is 50 rpm, the cylinder rotation speed is 300 rpm. This effect showed a positive result of the combined wind turbine with a vertical axis of rotation.

The main results include the following:

1. A laboratory sample of a combined wind turbine in the form of rotating cylinders with a fixed blade and a measurement procedure has been developed.

2. Mathematical modeling of aerodynamic characteristics of a rotating cylindrical wind turbine with a fixed blade in the air flow is carried out.

3. The aerodynamic characteristics of rotating cylindrical elements for the operation of a combined wind turbine at low wind speeds of the air flow are investigated:

- the dependence of the coefficients of drag and lift at different values of wind speed on the angle of inclination of the flow is constructed. Fixed blade of a rotating cylinder at different values of wind speed $\alpha = 0^0; 45^0; 90^0; 135^0; 180^0$ located at angles of inclination, with an increase in the air flow velocity, the drag and lift coefficients increase.

- the dependence of the drag coefficient on the Reynolds number is given at the number of revolutions of 300 rpm, 500 rpm and 700 rpm of rotating cylinders with a diameter of 4 cm rotating in the vertical direction. The air flow velocity was from 3 to 15 m/s. As the flow rate increases, the number of revolutions of the rotating cylinders increases, and the drag coefficient decreases.

- the magnitude of the forces acting on the cylinders with an increase in the flow rate as a result of the dependence of the thrust force of a combined wind turbine with a vertical axis of rotation on the flow rate decreases in the low-pressure zone and increases in the high-pressure zone. The lifting force of the cylinders during rotational movement also increases. The increase in the lifting force of the cylinders affects the increase in the lifting force of the wind turbine. Consequently, as the flow velocity increases, the lifting force of the wind turbine

increases. As the number of cylinder revolutions increased, the lifting force at a flow velocity of 15 m/s had a maximum value of 5.8 N, 7.2 N, 9 N.

4. The error of the comparative analysis of the theoretical and experimental values is 1-2%, which showed the high accuracy of numerical studies.

5. A prototype of a combined wind turbine in the form of rotating cylinders with a fixed blade was developed and assembled, which were studied at the landfill.

6. The power generation of the electric generator begins at a wind speed of 2.8 m/s, the rotation speed of the combined wind turbine is 50 rpm, the cylinder rotation speed is 300 rpm. This effect showed a positive result of the combined wind turbine with a vertical axis of rotation.

7. The thrust force was investigated under different climatic conditions, where positive results were obtained. It is established that with an increase in the flow slope, the thrust force of the wind turbine decreases, which corresponds to the physical flow pattern. However, with an increase in the air flow velocity, the value of the thrust force of the multi-blade wind turbine layout increases, which is also explained by an increase in the pressure force on the wind wheel.

The scientific and practical significance of the work is based on the creation and experiment of a wind turbine with a vertical axis of rotation. The results of the experiment show that it is possible to use an additional force driven by the Magnus effect that occurs when rotating cylinders with a vertical axis. This wind turbine can generate energy starting from a wind speed of 2.8 m/s. The efficiency of a wind turbine with a vertical axis of rotation can be seen in practice.

Practical significance of the work. According to the results of tests, research, development and technological works of KB "Tree Energy" LLP in Almaty, a test certificate of a model of a combined wind turbine made on the basis of a rotating cylinder with a fixed blade was drawn up and approved.

At the E. A. Buketov Karaganda University, the Faculty of Physics and Technology at the Professor Zh. S. Akylbayev Department of Engineering Thermophysics received an act of introduction into the educational process. The research results are used in lectures and practical seminars in the following disciplines: "Unconventional energy sources and resource conservation", "Renewable energy sources", "Basic principles and problems of modern wind power" for specialties 6B07103-Thermal power engineering, 7M07109801-Thermal Power Engineering and 6B11201 - Life safety and environmental protection.

Approbation of work and publications. The main results of the dissertation were reported and discussed at: Actual problems of thermal power engineering and applied thermophysics: Republican Scientific and Practical conference dedicated to the 80th anniversary of Professor Akylbayev Zh. S. (September 28, 2018) Karaganda, "Computing and Information Technologies in Science, Technology and Education": International Conference (September 25-28, 2018) Ust-Kamenogorsk, "The Future of Science - 2019" 7th International Youth Scientific Conference dedicated to the 55th anniversary of South Ural

State University (April 25-26, 2019) Kursk, 11th International Scientific Conference: Chaos and Structures in Nonlinear Systems. Theory and Experiment (November 21-22, 2019). - Karaganda.

Publications. The main results included in the dissertation are presented in 15 publications. 3 articles – published in publications included in the list of the CCSES MES RK, 2 works - in the materials of international conferences, 3 - in highly rated publications of foreign countries, 2 articles - in a journal included in the Thomson Reuters database with a non-zero impact factor and 1 article - in journals included in the Scopus database, 3 articles - in a peer-reviewed journal with a non-zero impact factor according to the RSCI database. A patent was obtained for a utility model "Blade of a wind power plant in the form of a rotating cylinder", No. 4043 dated 07.06.2019.

The structure and scope of the dissertation. The structure of the dissertation work is determined by the tasks, the solution of which is necessary to achieve the purpose of the dissertation. The dissertation consists of an introduction, 4 sections, conclusions, a list of used sources from 121 titles and an appendix, contains 136 pages of typewritten text. The work is illustrated with 78 figures and includes 8 tables.