

## Studying hybrid solar-wind devices in various methods

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**Abstract:** This work covers the issues of experimental research and mathematical and computer modeling of hybrid solar-wind power plants. The study analyzes the modes of joint operation of solar photovoltaic panels and wind generators, their energy production efficiency, stability under load, and dependence on climatic factors. Experimental tests are conducted in laboratory and real conditions, and the results obtained are confirmed and optimized through modeling. The possibilities of managing the energy balance of the hybrid system, its integration with battery systems, and the effective use of renewable energy sources are considered. The results of the study serve to increase the reliability of energy supply, ensure the continuity of electricity, and develop environmentally friendly energy technologies.

**Keywords:** solar energy, wind energy, photovoltaic panels, wind generator, experimental research, mathematical modeling, energy efficiency, renewable energy

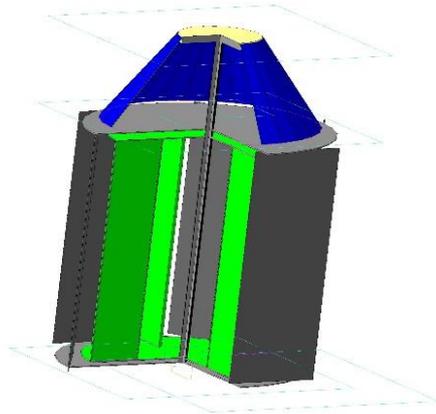
**Introduction.** The increase in the size and speed of wind turbines leads to an increase in the stress on the relevant parts of the mechanical energy transmission and especially on the braking system. The wind turbine braking system operates at high cycles, at high voltages and requires a high level of reliability and robustness in relation to its equipment. The brakes of wind generators must be automatically activated, taking into account the autonomous operation of the turbines. Typically, wind turbines are installed and operate away from constant human control, which makes maintenance difficult and expensive. Accordingly, they must operate reliably in adverse environmental conditions, often with excessive humidity and high temperatures. In recent years, small-capacity and vertical-axis devices have appeared among traditional energy devices. They have been proven in practice to have high efficiency due to their design and dynamic advantages over traditional horizontal-axis devices. In our country, there are seasonal winds, Bekabad and Kokand, with a speed of about 25 m/s. In addition, the average daily wind speed in different regions of Uzbekistan is 2.5 - 6.5 m/s. Traditional wind generators do not operate at wind speeds below 5 m/s. In almost all parts of Uzbekistan, there is no possibility of using these wind generators.

An important aspect of the problem is that in different regions of our country and at different wind speeds, including low wind speeds, there is a great need for wind generators designed for different capacities and operating effectively [1].

Based on the above problems, it can be noted that the purpose of the proposed device is to develop highly efficient and low-cost vertical-axis wind generators. Also, in our sunny homeland, the prospects for using "Sun-Wind" hybrid energy devices are great. Such a solution allows you to maximize the efficiency of the energy device. In other words, it is an urgent task to create laboratory samples of universal vertical-axis wind turbines, which can be used in various hybrid devices, using modern digital modeling technology, conduct experimental tests in natural conditions, bring them to an industrial model, and produce all the necessary technical and regulatory documents. It is precisely the achievement of a practical solution to these problems that is the main goal of this proposed innovative device.

Methods. In studying effective methods of converting solar energy into electricity and testing them in practice before applying them to industry, it is possible to change the materials of the solar panels made of photovoltaic cells. The Sentarus tead program is used to study their physical properties by modeling solar cells. The program has a number of advantages, in which it is possible to make solar cells of any size. It allows you to determine their physical properties by changing the material of the solar cell. Modeling solar cells using the Sentarus program is to determine changes in the conversion of energy from the sun into electricity. The program has a number of advantages, in which it is possible to make solar cells of any size. It allows you to determine their physical properties by changing the material of the solar cell. Using the Sentarus program, it is possible to create solar cells and make them from various materials. The Sentarus program also provides for making solar cells of any size and increasing their absorption coefficient. The Sentarus program uses solar cells [2].

The Sentarus program is used to increase the light flux falling on the solar cells by dropping them at different angles and calculating the current over time, voltage over power, temperature over time, and other various quantities of the solar cells. The flows, simple turbine structure, better self-starting properties, more orderly direction, and less noise. This reduces vibration and reduces the percentage of damage to the turbine structure. In addition, maintenance costs are low because the equipment is simple and easy to install. In recent years, many researchers have done various numerical and experimental studies. Aspect ratio, coverage ratio, blade profile, number of blades, and deflectors are the main factors. This directly affects the efficiency. Different numbers, shapes, sizes, and positions of blades all affect the performance of the turbine. The effects of rotor aspect ratio, rotor shape, gap between rotor blades, blade cross-section profile, and numerical performance characteristics are investigated by studying the pressure distribution on the blade surface under different rotor angles and speed ratios[3].



*Figure 1. Sample modeled using the Compass program.*

ANSYS software is compatible with AutoCAD, Compass, Coreldraw, Solidwork and NX. The performance of the six-bladed device is better than that of the two-bladed one, as shown by the increase in power factor according to the CFD simulation results. If a six-bladed deflector is installed, its speed can be increased. The results also showed that the power factor increases with the ratio. The results showed that the flow characteristics of the elliptical blade turbine were better than those of the traditional semicircular design. Ansys is an automated universal analysis software. The use of the CFX and CFD (computational fluid dynamics) sections of the program is required [4].

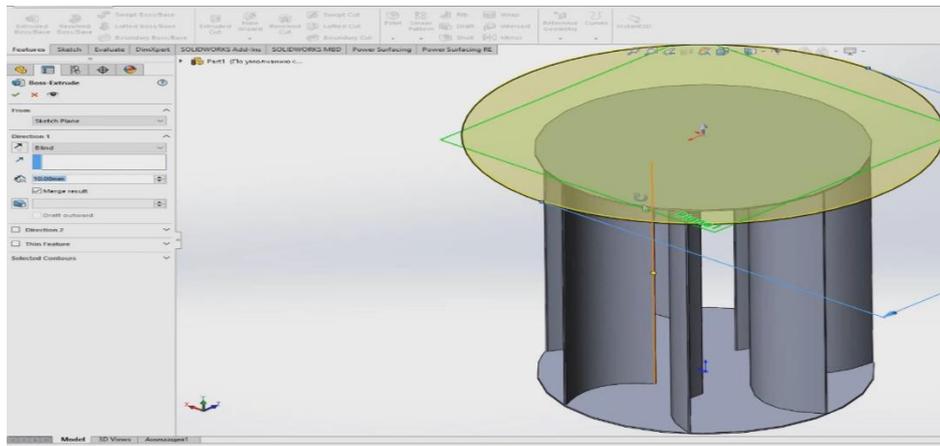


Figure 2. Design of a vertical axis wind turbine through the ANSYS DesignModeler window.

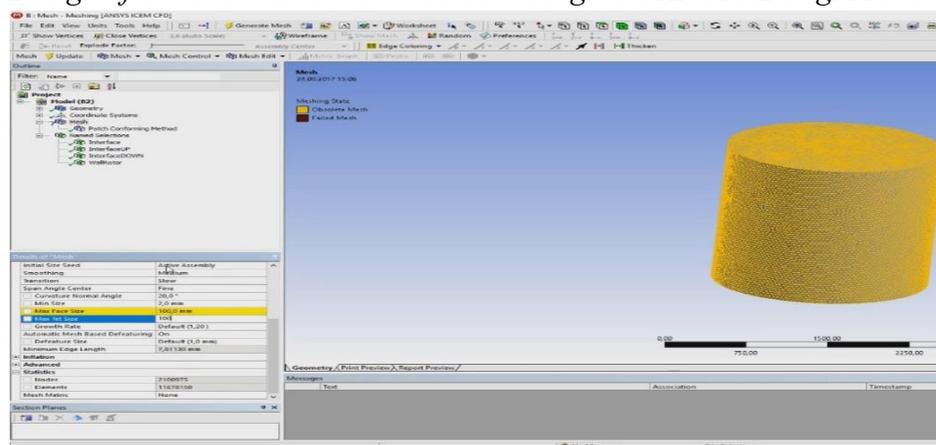


Figure 3. Meshing in a vertical-axis wind turbine.

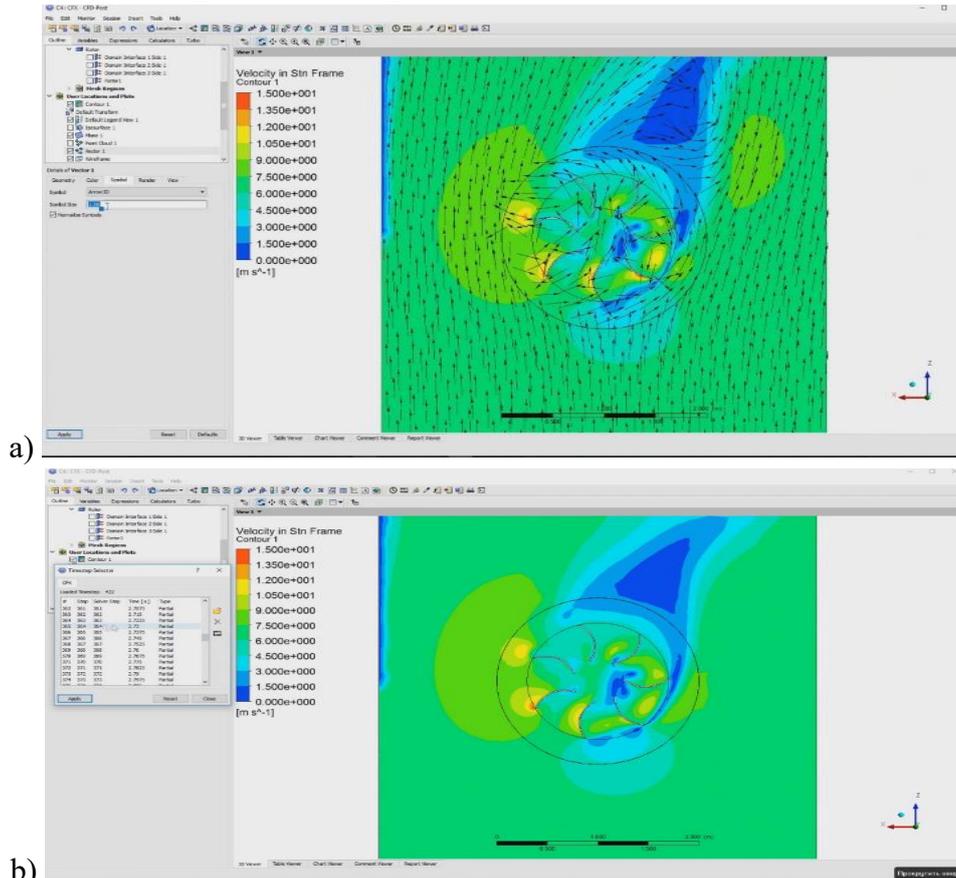


Figure 4. Visualization of wind speed direction in a vertical-axis wind device in the program.

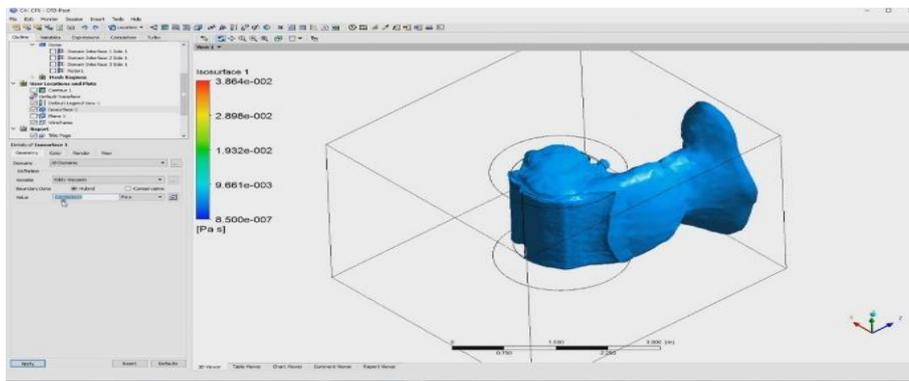


Figure 5. Visualization of wind effects on a vertical axis wind turbine.

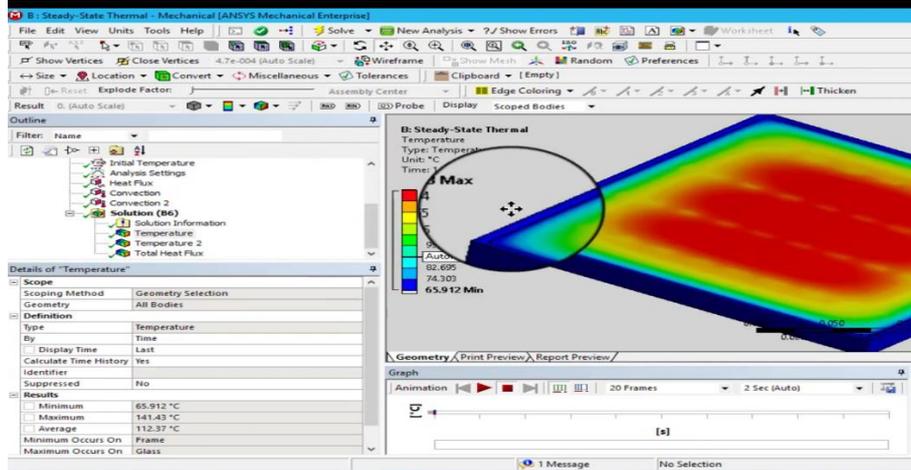


Figure 6. Temperature effect on a solar panel in a vertical axis wind device.

Results. When solar and wind energy are used together to generate electricity, the system becomes more reliable. Unlike solar modules, wind generators also produce cheap electricity. Such devices can be used in any situation, and these systems are designed to be combined with diesel generators and centralized power supply. In these energy systems, the accumulation of energy from primary sources occurs in their batteries with a voltage of 12 or 24 volts. Further, this direct current from stationary batteries is converted into electrical energy with a voltage of 220V and a frequency of 50Hz using an inverter. This type of power plant is designed for use in 50 Hz power grids and 220 V power consumers, as well as in urban areas with 12, 24 and 48 volts. Such power plants can be used as an emergency backup power source for existing household power grids, as well as in stationary conditions for emergencies or emergencies. Most of the classical wind generators currently widely used operate at wind speeds above 5 m/s. The next generation of conventional vertical axis wind generators operate at wind speeds above 3 m/s [5].



Figure 7. View of a vertical axis hybrid device.

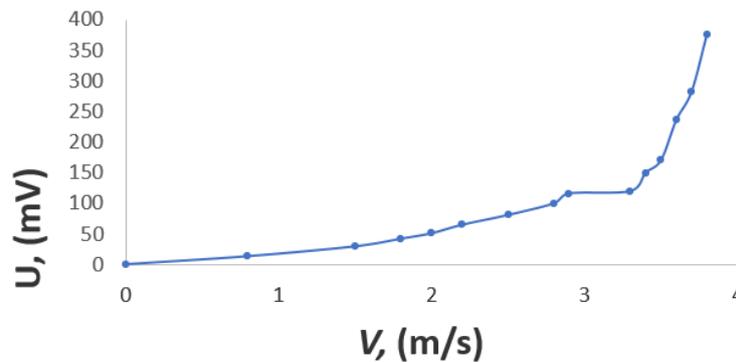


Figure 8. Graph of the dependence of the voltage of a wind generator on its rotation speed

The energy device we offer works when the wind speed is above 1.5 m/s. This is convenient for use in all regions of Uzbekistan. If we pay attention, the incoming wind hits both blades, but due to the convexity of the blade, the blade can rotate. It only starts to move when the wind speed is above 3 m/s. If we change the direction of the wind hitting one blade, then opposing moments will not be created in the two blades and the blade will be able to operate even at low speeds, i.e. at speeds greater than 1.5 m/s. In addition, it provides higher efficiency and lower noise compared to other wind generators. The total mass of the device is 2034 g, while the wind turbine is 1813 g. The rotor starting speed is 1.5 m/s, and the rotation speed does not exceed 400 rad/m, and the pressure on the working parts is almost evenly distributed. This increases the service life. It works effectively even at low wind speeds [6].

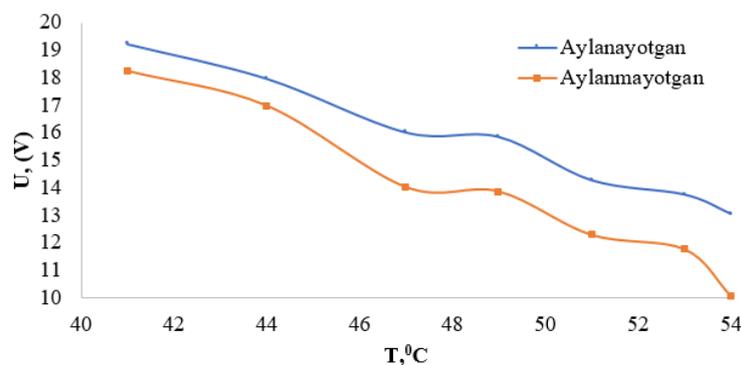


Figure 9. Graph of the dependence of the operating voltage of a rotating and non-rotating photovoltaic device on the surface temperature

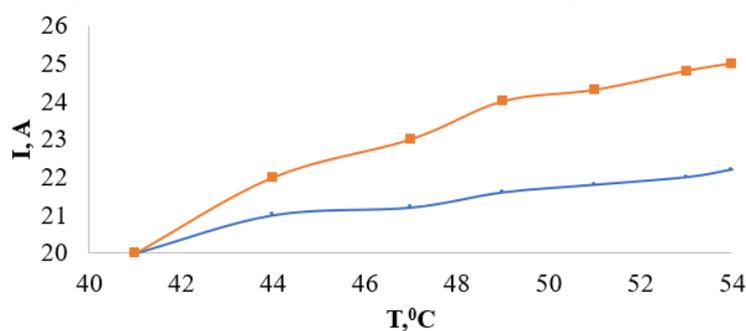


Figure 10. Short-circuit current of rotating and non-rotating photovoltaic devices as a function of surface temperature

Analysis. The above programs help to obtain many approximate results of the work. Among them, using the Sentarus program, it is possible to create solar cells and make them from various materials. The Sentarus program also provides for the creation of solar cells of any size and increasing their absorption coefficient. The Sentarus program uses solar cells. Through the Sentarus program, it is possible to increase the light flux falling on the solar cells, to make them at different angles and to

calculate the current versus time, voltage versus power, temperature versus time and other various quantities of the solar cells. Modeling is carried out directly in the online system with the countries of Spain, Germany and China. Although the power indicators of the Savonius turbine are 20% lower, the gravity-based turbine has many advantages, including that this type is suitable for low-speed wind regions. The flows, simple turbine structure, better self-starting properties, the direction is more orderly and the noise is less. This reduces vibration and reduces the risk of damage to the turbine structure. In addition, maintenance costs are low because the equipment is simple and easy to install.

The main focus of the study of hybrid solar-wind energy systems was to determine their energy efficiency, stable performance characteristics, and dependence on external environmental factors. During the analysis, experimental results and data obtained through modeling were compared, and the capabilities of the system in real operating conditions were assessed [7].

Experimental studies have shown that the change in solar radiation intensity and wind speed over time directly affects the total power generated by the hybrid device. While the maximum power point of the solar panels was observed mainly during the daytime, the efficient operation of the wind generator allowed for energy production in the evening and at night. As a result, interruptions in the total energy supply were significantly reduced due to the complementarity of energy sources.

At the modeling stage, a mathematical model of the hybrid system was created, which took into account the main technical parameters of solar panels, wind generator, inverter and energy storage systems. Using computer simulations, the system's operating modes were analyzed in different climatic conditions. The modeling results were found to be in high agreement with experimental data, confirming the reliability of the developed model.

Also, the analysis process studied the effects of energy generation losses, voltage and current fluctuations, and load changes on system stability. It was found that the use of an energy storage device plays an important role in increasing the efficiency of the hybrid system and ensuring uninterrupted electricity supply to consumers. It was shown that it is possible to increase the efficiency of power distribution between energy sources by optimizing control algorithms [8].

**Conclusion.** In general, the conducted analyses confirm that hybrid solar-wind installations are an environmentally friendly, economically feasible and highly reliable system in energy supply compared to traditional energy sources. In this work, the issues of studying hybrid solar-wind energy installations using experimental and modeling methods were analyzed. As a result of the studies, it was found that the integration of solar panels and wind generators into a single energy system is of great importance in ensuring the stability and continuity of energy production. Experimental tests made it possible to assess the efficiency of hybrid systems in real climatic and weather conditions, while mathematical and computer modeling methods served to optimize system parameters, reduce losses in energy production, and improve control algorithms.

The results showed that hybrid solar-wind installations have high reliability and efficiency compared to separate energy sources, and are a promising solution, especially for providing energy to areas far from power grids. The models developed during the research will serve as a solid scientific basis for further evaluation of technical and economic indicators of the installations, their integration with energy storage systems, and the introduction of intelligent control systems.

To achieve the goal, the following tasks were performed:

- 1) digital modeling of a universal design wind turbine with a vertical axis and low wind speed using the most modern programming languages “S#9.0” and “Unity”;
- 2) preparation of a pilot version of a universal design wind turbine with a vertical axis and low wind speed, and preliminary testing;

- 3) to substantiate the optimal geometric and economic-energetic parameters of a universal wind turbine using digital modeling technology and experimental testing in natural conditions;
- 4) to prepare a pilot version of the “Wind Power Plant” based on a vertical-axis and low-wind speed wind turbine with a universal design, and to conduct preliminary tests;
- 5) to prepare a pilot version of the “Sun-Wind” hybrid power plant based on a vertical-axis and low-wind speed wind turbine with a universal design, and to conduct preliminary tests;
- 6) to create industrial samples of the “Wind Power Plant” and the “Sun-Wind” hybrid power plant, and to develop technical regulatory documents. The proposed vertical-axis wind turbine and the power plant created on its basis have higher efficiency than analogues and are intended for widespread use in regions with low wind speeds.

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