POWER MACHINERY

UDC 121.548.5(045)
DOI:10.18372/1990-5548.78.18275

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INTELEGENCE DESIGN OF HYBRID VERTICAL-AXIS ROTORS

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Abstract—*The work is devoted to the necessity of creating the vertical-axis rotors of wind power stations in the urban area, which can be placed on roofs and makes it possible to increase their energy productivity by 60-70%. It is shown that the locations of such rotors on roofs has its own characteristics, which consists in the need to take into account the shape of the topography of the house, its storey, the direction and speed of the winds above it, and others. Examples of implementation of wind farms are considered and it is proven that their energy efficiency can be increased due to the use of hybrid vertical-axis rotors, which consist of a combination of Darrieus and Savonius rotors, where the Darrieus rotor is the main source(s) of wind energy conversion into the electric one, while the Savonius rotor(s) provide the acceleration of the Darrieus rotors. For the implementation it has been used the genetic algorithm. An inelegance design system has been developed. An example of the application of this system for the design of a hybrid rotor is given.*

Index Term—Automatic control system; Savonius rotor; Darrieus rotor; wind turbine; genetic algorithm; ANSYS.

I. INTRODUCTION

In the 21st century, it is difficult to imagine Ukraine or any other developed countries of the world without renewable electricity generation.

Growing interest in alternative energy sources with global warming. Now the use of wind energy is becoming more attractive. Wind energy is the most widely used among renewable sources. In places with good wind conditions, it successfully competes with traditional fuel or nuclear power plants. In some countries (Germany, Denmark, Spain, India and partly the USA) it has turned into a separate industry. According to the International Renewable Energy Agency (IRENA), over the past two decades, the capacity of wind energy in the world has increased almost 75 times – from 7.5 GW in 1997 to 565 GW in 2018. Today, the capacity of wind power plants is 730 GW.

Modern wind energy installations are quite diverse both in terms of types and capacities, and can be used for various purposes, starting from charging batteries to powering various objects (individual houses, agricultural farms, etc.) to supplying electricity to the centralized power supply network.

By using hybrid vertical-axis rotors, you can get the required amount of W for stable support of individual areas and remote settlements.

II. CLASSIFICATION OF WIND ENERGY INSTALLATIONS

A wind engine directly converts the energy of the wind flow into mechanical energy, which is then used to drive various mechanisms and machines (for example, pumps) or is transformed into electrical energy [1]. Wind engines, used as a drive of a wind power generator, are divided into two main types:

- horizontal-axial (Fig. 1), characterized by collinearity of the vector of the angular speed of rotation of the wind engine and the axial component of the vector of the speed of the wind flow.
- vertical-axial (Fig. 2), characterized by the orthogonality of the vectors of the angular speed of rotation of the wind engine and the axial component of the vector of the speed of the wind flow.
- hybrid rotors with a vertical axis (Fig. 3), which combine Savonius and Darier designs, represent an innovative approach to wind turbine technology. Both Savonius and Darrieus are types of vertical-axis wind turbines with distinct characteristics, and their integration aims to exploit the strengths of each design.

III. AUTOMATION SCHEME FOR THE DESIGN OF HYBRID VERTICAL-AXIS ROTORS

To solve the problem related to the intelegence design, it is necessary to develop an intelegence design system.

In turn, the calculation of rotor designs includes:

1) calculation of the aerodynamic parameters of the Darrieus rotor;

2) determination of optimal geometric parameters of the Darrieus rotor using an intelligent algorithm;

3) determination of the determination of the output data of the Savonius rotor based on the calculation of the starting torque of the Darrieus rotor using an intelligent algorithm;

4) determination of the aerodynamic parameters of the Savonius rotor using an intelligent algorithm;

5) optimization of Savonius rotor parameters using an intelligent algorithm.

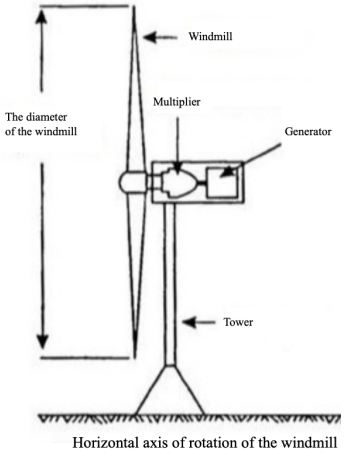

Fig. 1. Wind turbine with a horizontal axis of rotation

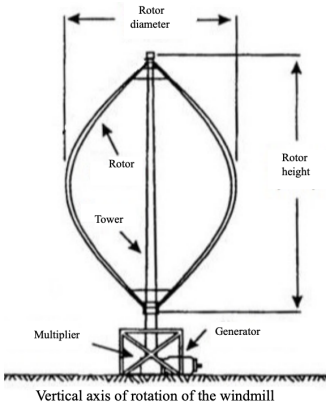

Fig. 2. Wind turbine with a vertical axis of rotation

Fig. 3. Wind turbine with a hybrid rotor

The structural diagram is shown in Fig. 4.

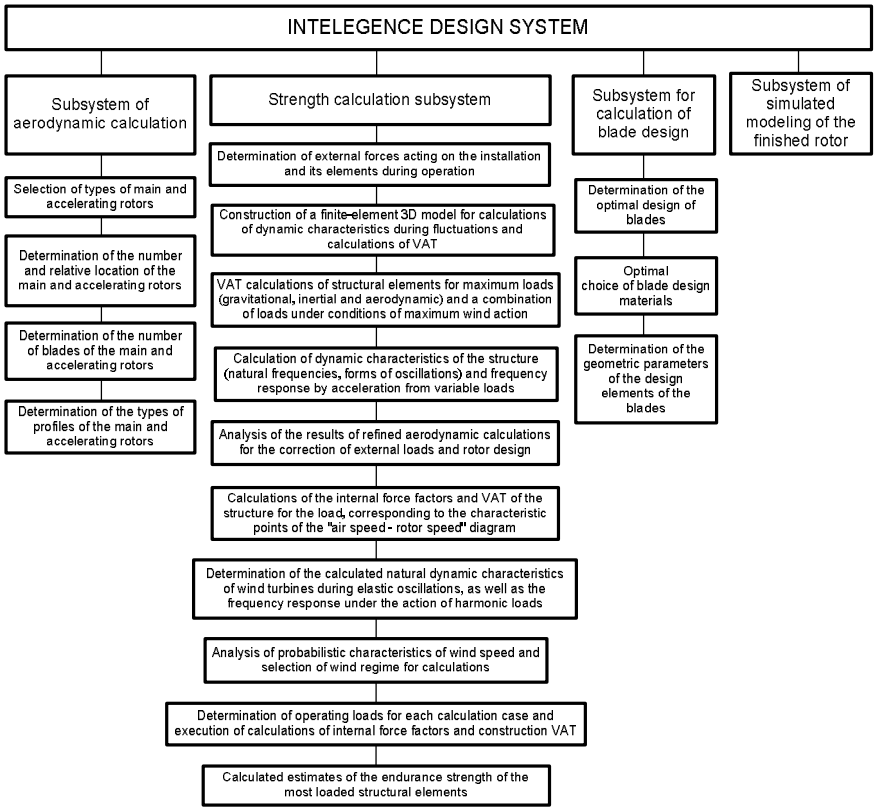

Fig. 4. Intelligence design system

For convenience, a system of aerodynamic calculation was developed Fig. 5.

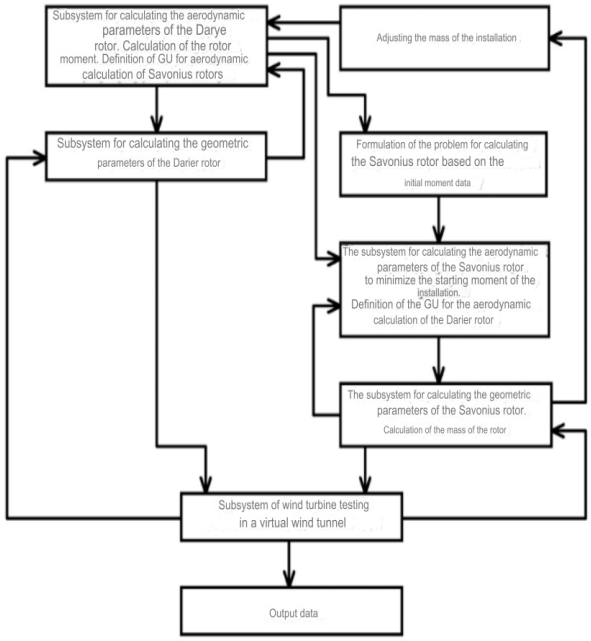

Fig. 5. Aerodynamic calculation system

IV. Using the Genetic Algorithm for the Design of Hybrid Vertical-Axis Rotors

In this work, a genetic algorithm was used to find the optimal parameters (Fig. 6). A genetic algorithm is an evolutionary algorithm inspired by the processes of natural selection and genetic evolution [5]. Genetic algorithms are used to solve optimization and search problems, modeling according to these evolutionary principles. Using it, you can get the optimal parameters of the rotor, such as its width, height, number of rotors, their relative placement and price.

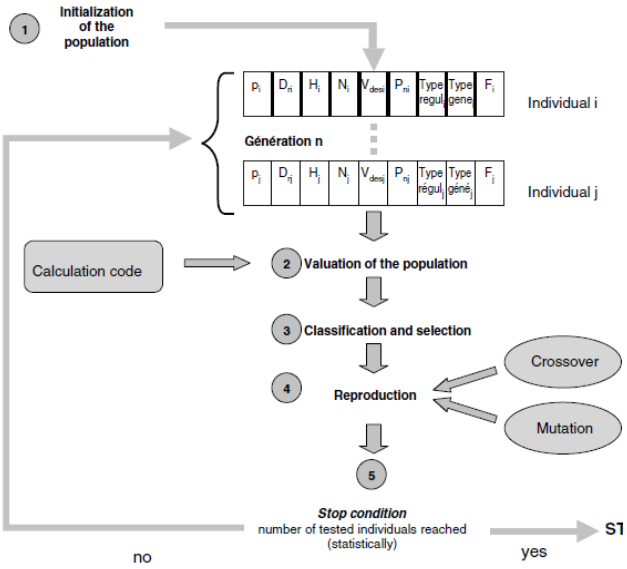

Fig. 6. Automated design system

Using the ANSYS program, you can obtain finite element analysis and, accordingly, the optimal parameters of the rotor.

The power produced by the wind generator is determined based on the power factor (C_p) including the tip speed factor (λ) and the angle of inclination (β) parameters. The tip velocity factor λ is often adjusted over time because it is determined by the angular velocity of the turbine rotor. Feedback from the turbine rotor to the tip speed ratio can be created in a closed loop.

V. Software Structure of the Automated Design System

To optimally obtain the necessary parameters, the software and its operation scheme were developed. Fig. 7.

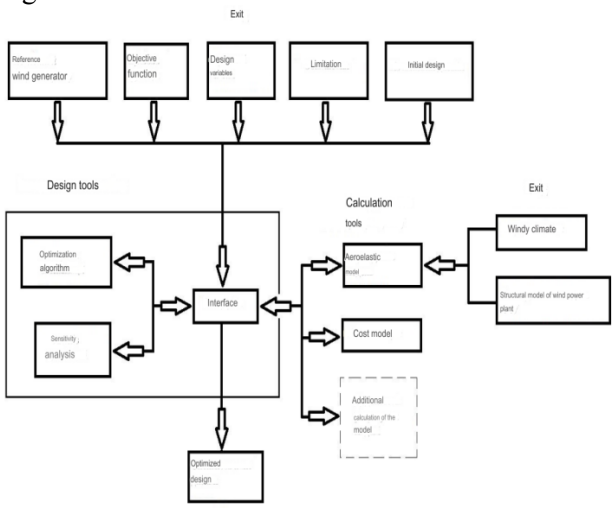

Fig. 7. Structural diagram of software optimization

With the help of the scheme, software was developed where you can specify the optimization goals and the genetic algorithm settings you need Figs 8 and 9 (permissible error for fitness value, maximum number of generations, population size, proportion of individuals formed by crossing, etc.).

Fig. 8. Type of software for wind turbine configuration

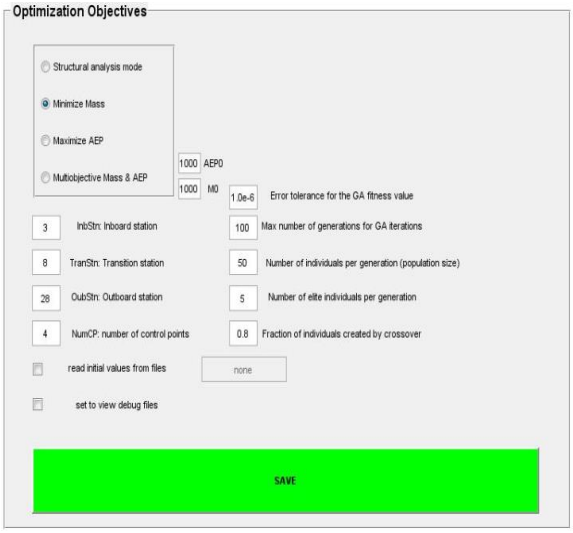

Fig. 9. Type of software for wind turbine optimization

VI. CONCLUSIONS

The paper developed a new approach for the construction of hybrid wind energy installations with a vertical-axis rotor, using elements of artificial intelligence. The application of the proposed approach will improve the efficiency of wind energy installations.

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Received September 18, 2023

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В. М. Синєглазов, О. В. Станіславчук. **Розумний дизайн гібридних роторів з вертикальною віссю**
Роботу присвячено необхідності створення в міській місцевості вертикально-осьових роторів вітрових електростанцій, які можуть розміщуватися на дахах і дають змогу підвищити їх енергопродуктивність на 60–70%. Показано, що розташування таких роторів на дахах має свої особливості, які полягають у необхідності

врахування форми рельєфу будинку, його поверховості, напрямку та швидкості вітрів над ним та ін. Розглянуто приклади впровадження вітроенергетичних станцій та доведено, що їх енергоефективність можна підвищити за рахунок використання гібридних вертикально-осьових роторів, які складаються з комбінації роторів Дар'є та Савоніуса, де ротор Дар'є є основним джерелом перетворення енергії вітру в електричну, а ротор(и) Савоніуса забезпечують прискорення роторів Дар'є. Для реалізації використано генетичний алгоритм. Розроблено систему дизайну неелегантності. Наведено приклад застосування цієї системи для проектування гібридного ротора.
Ключові слова: інтелектуальна система автоматизованого проектування, ротор Савоніуса, ротор Дар'є, генетичний алгоритм, вітроенергетична установка, ANSYS.

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Напрям наукової діяльності: аеронавігація, управління повітряним рухом, ідентифікація складних систем, вітроенергетичні установки, штучний інтелект.
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