DOI: https://doi.org/10.15276/ict.02.2025.80
UDC 004.942:621.548

Creating a model of aerodynamic processes in a double turbine "ARSIRY" or wind power complexes

Vasily A. Arsiriy[1)]
Doctor of Engineering Sciences, Professor of the Department of Heat Supply and Ventilation
ORCID: https://orcid.org/0000-0003-3617-8487; vasyly.arsiriy@gmail.com
Oleg V. Kravchenko[1)]
PhD, Senior Lecturer of the Department of Heat Supply and Ventilation,
ORCID: https://orcid.org/0000-0001-9765-2344; sir.Kravchenko777@gmail.com
Oleksandr S. Onyshchenko[1)]
Postgraduate Student of the Department of Heat Supply and Ventilation
ORCID: https://orcid.org/0009-0000-4729-2993; alexander.cyclon@gmail.com
Serhii B. Kondratyev[2)]
Senior Lecturer, IT of the Designing Training Department,
ORCID: https://orcid.org/0000-0003-4975-5757; kondratiev@op.edu.ua
Andrii Y. Zasidko[2)]
Postgraduate Student of the Department of Information Systems
ORCID: https://orcid.org/0000-0001-5197-0435; andzasidko@op.edu.ua
[1)] Odesa State Academy of Civil Engineering and Architecture, 4, Didrikhson Str. Odesa, 65029, Ukraine
[2)] Odesa Polytechnic National University, 1, Shevchenko Ave. Odesa, 65044, Ukraine

ABSTRACT

The failure of power generation facilities or transformer substations leads to system failures with long-term power outages of a significant number of consumers. To ensure the stability of the power system, it is necessary to develop distributed electricity production, which will be carried out by small power plants directly near the places of its consumption. The paper shows the possibility of using wind turbines as one of the elements in distributed electricity generation complexes. A comparative analysis of existing samples and their operating conditions showed the shortcomings of existing systems. Despite the high perfection and efficiency of samples with a horizontal axis, they are not suitable for use in urban areas or heavily intersected terrain. Samples with a vertical axis (Savonius and Darrieus turbines) have a low power factor. To overcome existing contradictions, a fundamentally new turbine with improved geometry was developed, the design of which allows the use of wind flow energy twice. Previous studies have shown a significant improvement in the efficiency of combined wind turbines based on the "ARSIRY" type turbine and the possibility of their use in wind conditions of relatively low quality (low speed, increased turbulence, frequent change in flow direction, etc.). The use of the Bernoulli equation, which represents the sum of the three components of the specific energy of the flow in the form of the "total pressure" indicator, is justified for creating a model of aerodynamic processes in a double turbine of the "ARSIRY" type. Analysis of the features of air movement in the flow part of a double turbine using the equation provides an explanation of the principle of double use of flow energy. The key importance of reducing the resistance of individual parts of the turbine for increasing turbine power through rational use of air velocity at a given value of the energy potential of the flows is shown.

Keywords: Model of aerodynamic processes; double turbine; "ARSIRY" type turbine; reducing the resistance; Renewable Energy Sources

The study aims. Significant damage to energy facilities in the conditions of full-scale armed aggression of the Russian Federation showed the vulnerability of the energy system of Ukraine. The failure of electricity generation facilities or transformer substations leads to system accidents with long-term power outages of a significant number of consumers.

To ensure the stability of the energy system, it is necessary to develop decentralized electricity production, which will be carried out by small power plants directly near the places of its consumption [1]. Distributed energy generation can be implemented on the basis of renewable energy components. As a rule, these are wind power plants, solar panels, biogas plants, small hydroelectric power plants etc [2].

According to Ukrainian experts, Ukraine has quite large wind energy resources. The annual technically achievable energy potential of wind energy in Ukraine is equivalent to 10.5 million tonnes of oil equivalent (Mtoe) and its use allows saving about 13 billion m^3 of natural gas annually.

This is an open access article under the CC BY license (https://creativecommons.org/licenses/by/4.0/deed.uk)

The above indicators correlate with the forecasts of scientists from Stanford University in the USA regarding the transition of the energy sector of most countries in the world to alternative energy sources.

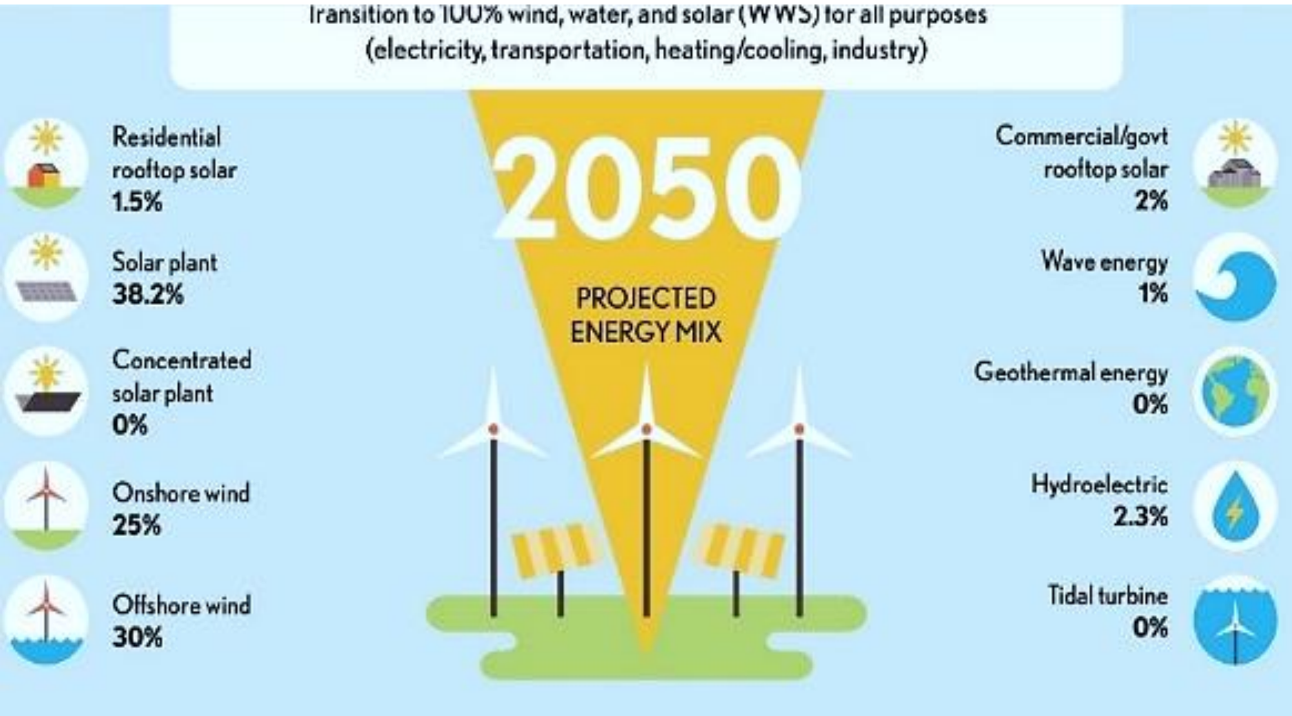

Fig. 1. **Prospects for the transition to water, wind and solar energy in Ukraine**

State of the problem. The current state of renewable energy generation has a number of significant drawbacks. For example, seasonal and daily fluctuations in indicators (temperature differences, frequent changes in wind speed and direction, etc.) make electricity production poorly predictable and sometimes uncontrolled. In addition, modern models of wind turbines with a horizontal axis are not suitable for use in urban areas or in very rough terrain.

Wind turbines with a vertical axis known for simplest design and have a number of advantages over the above constructions. They can operate in conditions of high turbulence; their operating parameters do not depend on the wind direction. It should also be noted the low wind speed required for self-starting (up to 2 m/s). As a disadvantage: low efficiency and, as a result, a low level of average annual electricity production.

ISSN 2522-1523 (Online) Smart Energy Grids and Microgrids

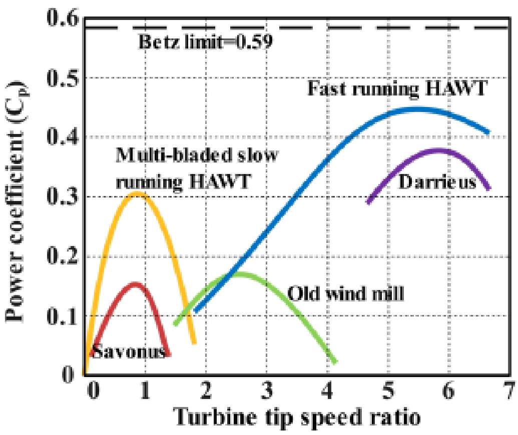

Fig. 2. **Dependence of power factor on tip speed ratio of main types of wind turbines**

To use vertical axis complexes, it is necessary to increase the efficiency (power coefficient). Since in Ukraine, wind speeds only in coastal regions have average values within V_1 = 3-6 m/s. Winds in European countries have a range of average speeds V_2 = 5 – 10 m/s.

The corresponding generation of specific electric power of the turbine N_{el} [Watt], depend on the area of the flow section of the turbine S = 1 m^2 and can be calculated by the formula:

$$N_{el} = 0{,}5\ C_P * \rho V^3;[Watt] \tag{1}$$
$$N_{ideal} = \rho V^2/2 * Q = \rho V^2 *(V*S).$$

The main indicator of the quality of wind turbine design is the power ccoefficient of turbines (rotors) of wind generators. $C_P = N_{el} / \rho V^3 S$. For the speed range V_2, the power ccoefficient of wind turbines can reach C_P = 0.4. However, at lower wind speeds (or at higher) this figure can decrease significantly.Purpose of the work.

Justification for dual use of wind energy due to the special design of the "ARSIRY" turbine to increase the efficiency of wind turbine-based complexes.

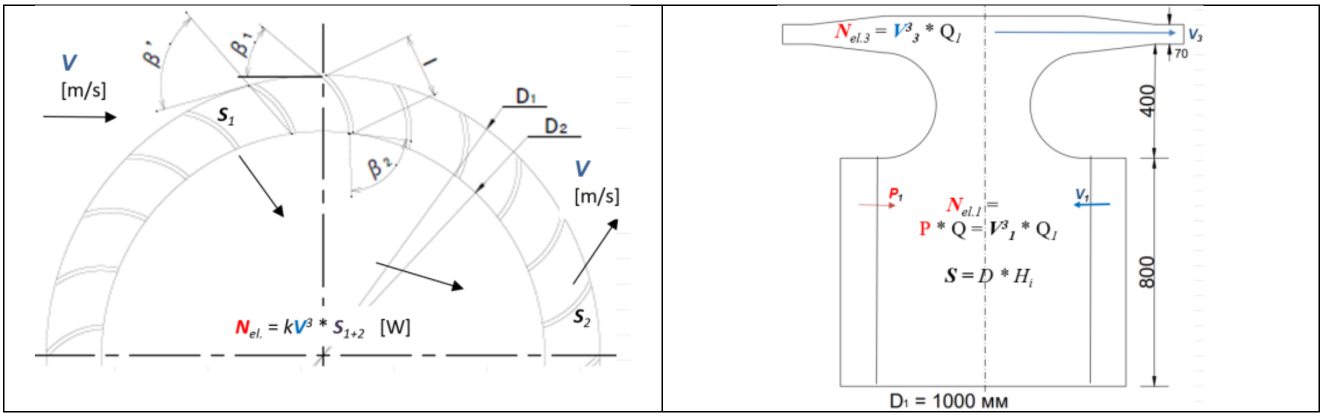

Fig. 3. **Banky's turbine and double turbine "ARSIRY" for the wind power complex**

In order to expand the possibilities of using wind energy for electricity generation in the south of Ukraine, a design of a double turbine has been developed, which can increase the specific electricity generation. Experiments have shown the possibility of increasing the performance of turbines due to the double use energy of the wind flow [5, 6].

Reducing the resistance of parts of the wind turbine ensures an increase in turbine power due to the rational use of air velocity at a given value of the energy potential of the flows.

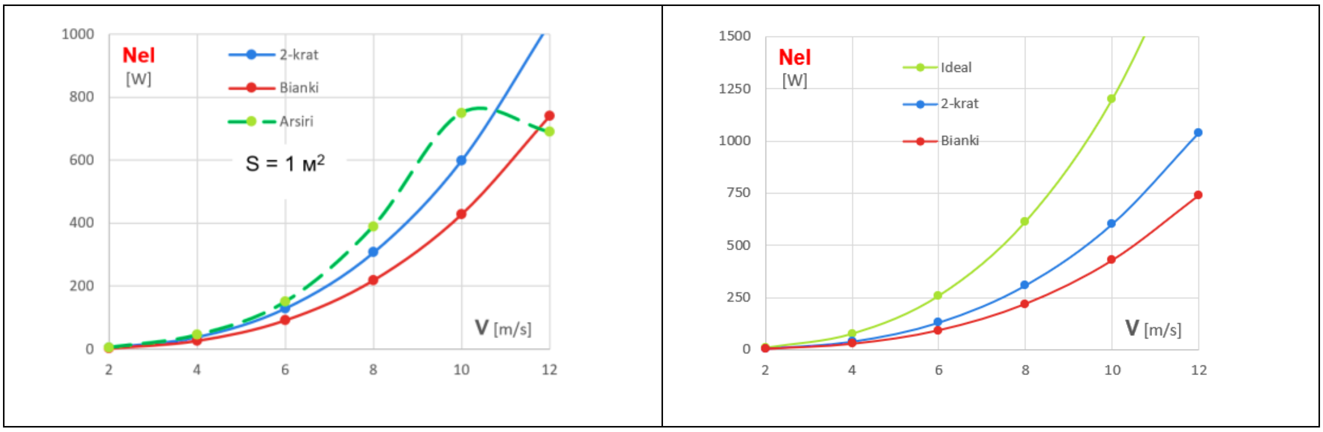

Fig. 4. **Electrical power of the Nel wind turbine with dimensions D = 1m and H = 1m**

For known wind turbines of the vane type, the priority average wind speed is considered to be Vc = 7.5 – 12.5 m/s. For the Dareus wind turbines type the priority wind speed is Vc = 5 – 8 m/s, and the initial speed starts from Vstart = 1.0 m/s. In this case, the installation of wind turbines will be economically justified. For Ukraine, it is considered advisable to use wind turbines with a wind speed range of Vc = 4.5 – 5.5 m/s [3, 4].

Results. On special equipment, studies of new type double turbine of the “ARSIRY” type were carried out to create rooftop wind power complexes. Such complexes can be widely used in high-rise buildings, as well as for individual power supply of private houses. Tests at the stands showed that the “ARSIRY” type turbine operates at wind speeds of less than 4m/s, which makes it possible to use them widely.

The justification of the features of air movement in the flow part of the double turbine can be done by the Bernoulli equation for an ideal fluid, which represents the sum of the three components of the specific energy of the flow in the form of the “total head” – H:

$$H = e = \cancel{\rho g z_1} + P_1 + \rho V_1^2/2 = \cancel{\rho g z_2} + P_2 + \rho V_2^2/2 = \text{const}; \text{ [Pa]} \qquad (2)$$

For wind flows, the height component can be neglected, so the equation has two parts of energy: potential – P and dynamics – $\rho V_2^2/2$. Fig. 5 shows a diagram of the process model in a double turbine.

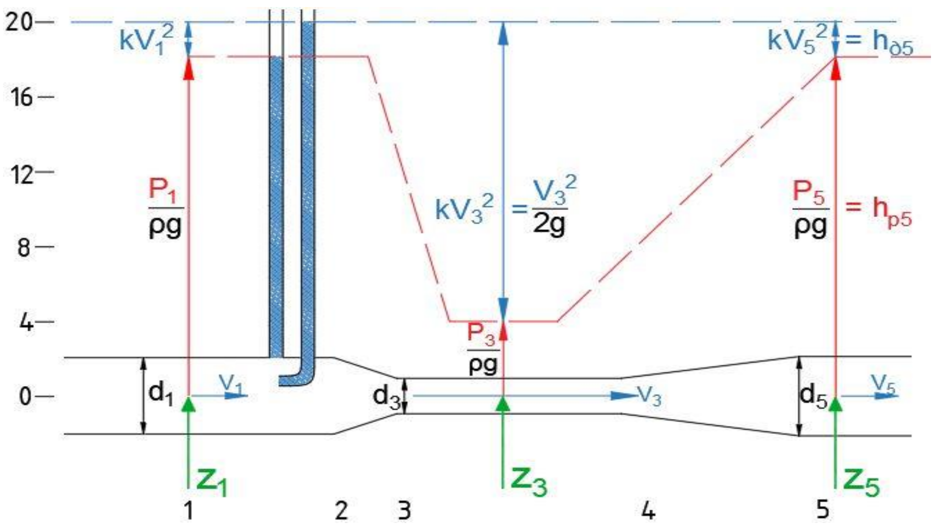

Fig. 5. **Model of fluid motion according to the Bernoulli equation**

Analysis of the components of the Bernoulli equation for an ideal fluid (2) provides an explanation the principle of the double use energy of the flow. The lower part gets the flow with the real wind speed V_1 and the maximum potential component – pressure P_1. In the lower part, the first potential component of power is formed.

$$N_{flow.1} = P_1 * Q = P_1 * (V_1 * S_1) = = V^3{}_1 * S_1; \quad \text{[Watt]} \qquad (3)$$

In the middle part, the flow turns 90° and exits the upper part with an increase in velocity proportional to the decrease in cross-section area. In direction, the velocity component at the flow outlet is close to a tangential circle and is directed in the opposite direction to the direction of turbine rotation to ensure the maximum dynamic energy component, which creates additional force with the actual flow velocity V_3.

$$N_{flow.3} = kV_3^2 * Q = kV_3^2 * (V * S_2) = V_3^3 * S_3; \quad \text{[Watt]} \qquad (4)$$

In a double turbine, the real power, taking into account the efficiency coefficient, can be calculated using the equation.

$$N_{gen} = N_{flow.1} + N_{flow.3}; \qquad [Watt] \tag{5}$$

Therefore, in the classification of turbine designs, it is possible to introduce the name double or potential-dynamic turbine.

Conclusions. A double turbine allows you to use the energy of the wind flow twice. To analyze the processes in the Banky turbines and the double "ARSIRY" turbine, it is advisable to use the Bernoulli equation.

An important factor in increasing the power and efficiency of turbines is the reduction of resistance to flow parts, which improves the dynamics of air movement and increase the power factor.

REFERENCES

1. "On Alternative Energy Sources". *Law of Ukraine, the Official Bulletin of the Verkhovna Rada of Ukraine (BVR)*. 2003; 24: 155. – URL: https://zakon.rada.gov.ua/laws/show/555-15#Text.

2. Gvozdiy V. "Why Ukraine should develop distributed generation". *GOLAW*. 2025. – URL: https://golaw.ua/ua/insights/energy-alert/chomu-ukrayini-varto-rozvivati-rozpodilenu-generacziyu.

3. Дудюк Д. Л., Мазепа С. С, Гнатишин Я. М. «Нетрадиційна енергетика: основи теорії та задачі: Навч. посібник». *Львів*. 2009.

4. Beri H., Yao Y. "Double Multiple Stream Tube Model and Numerical Analysis of Vertical Axis Wind Turbine". *Energy and Power Engineering*. 2011. DOI: https://doi.org/10.4236/epe.2011.33033.

5. Shigemitsu T., Fukutomi J., Toyohar, M. "Performance and flow condition of cross-flow wind turbine with a symmetrical casing having side boards". *International Journal of Fluid Machinery and Systems*. 2016; 9 (2). DOI: https://doi.org/10.5293/IJFMS.2016.9.2.169.

6. Hameed M. S., Afaq S. K. "Design and analysis of a straight bladed vertical axis wind turbine blade using analytical and numerical techniques". *Ocean Eng*. 2013; 57: 248–255. DOI: https://doi.org/10.1016/j.oceaneng.2012.09.007.

DOI: https://doi.org/10.15276/ict.02.2025.80
UDC 004.942:621.548

Створення моделі аеродинамічних процесів у двократній турбіні "ARSIRY" для вітроенергетичних комплексів

Арсірій Василь Анатолійович[1)]
Д-р техніч. наук, професор каф. Теплогазопостачання і вентиляції
ORCID: https://orcid.org/0000-0003-3617-8487; vasyly.arsiriy@gmail.com
Кравченко Олег Володимирович[1)]
PhD, старший викладач каф. Теплогазопостачання і вентиляції
ORCID: https://orcid.org/0000-0001-9765-2344; sir.Kravchenko777@gmail.com
Онищенко Олександр Сергійович[1)]
Аспірант каф.Теплогазопостачання і вентиляції
ORCID: https://orcid.org/0009-0000-4729-2993; alexander.cyclon@gmail.com
Кондратьєв Сергій Борисович[2)]
Старший викладач каф. Штучного інтелекту та аналізу даних
ORCID: https://orcid.org/0000-0003-4975-5757; kondratiev@op.edu.ua
Засідько Андрій Ярославович[2)]
Аспирант каф. Інформаційних систем
ORCID: https://orcid.org/0000-0001-5197-0435; andzasidko@op.edu.ua
[1)] Одеська державна академія будівництва та архітектури, вул. Дідріхсона, 4. Одеса, 65029, Україна
[2)] Національний університет «Одеська політехніка», пр. Шевченка, 1. Одеса, 65044,Україна

АНОТАЦІЯ

Виведення з ладу об’єктів генерації електроенергії або трансформаторних підстанцій призводить до системних аварій з довготривалим знеструмленням значної кількості споживачів. Для забезпечення стійкості енергосистеми необхідний розвиток розподіленого виробництва електроенергії яке буде здійснюватися невеликими енергетичними установками безпосередньо біля місць її споживання.

В роботі показана можливість використання вітроустановок як одного з елементів у комплексах розподіленої генерації електроенергії. Порівняльний аналіз існуючих зразків а також умов їх експлуатації показав недоліки існуючих систем. Не зважаючи на високу досконалість та ефективність зразків з горизонтальною віссю вони не придатні для використання в міській забудові або сильно пересічній місцевості. Зразки з вертикальною віссю (турбіни Совоніуса та Дарьє) мають низький коефіцієнт потужності. Для подолання існуючих протиріч була розроблена принципово нова турбіна з покращеною геометрією, конструкція якої дозволяє двічі використовувати енергію вітрового потоку. Попередні дослідження показали суттєве покращення показників ефективності комбінованих вітроустановок на основі турбіни типу «ARSIRY» та можливості їх використання в вітрових умовах відносно низької якості (невелика швидкість, підвищена турбулентність, часта зміна напрямку потоку тощо).

Обгрунтовано використання рівняння Бернуллі яке представляє суму з трех складових питомої енергії потоку у вигляді показника «повний напір» для створення моделі аеродинамічних процесів в двократній турбіні типу «ARSIRY». Аналіз особливостей руху повітря у проточній частині двократної турбіни з використанням рівняння дає пояснення принципу двократного використання енергії потоку.

Показано ключове значення зниження опорів окремих частин турбіни для збільшення потужності турбіни за рахунок раціонального використання швидкості руху повітря при заданій величині енергетичного потенціалу потоків.

Ключові слова: модель аеродинамічних процесів; подвійна турбіна; турбіна типу «АРСІРІ»; зменшення опору; Відновлювані Джерела Енергії