The European Journal of Technical and Natural Sciences 2024, No 3–4
ISSN 2414-2352

PREMIER Publishing
ppublishing.org

Section 3. Electrical engineering

DOI:10.29013/EJTNS-24-3.4-15-20

AN ALGORITHM FOR DESIGNING A HYBRID WIND TURBINE WIND WHEEL

Babakhan Shokhrukh Abdilkasymuly [1]***,***
Kokanbay Yernar Zhaksylykuly [1]***, Pernebaev Kuanysh Orazbekuly*** [1]

[1] International Kazakh-Turkish University named after Khoja Ahmed Yasawi

Cite: *Babakhan Sh.A., Kokanbay Y.Zh., Pernebaev K.O. (2024). An algorithm for designing a hybrid wind turbine wind wheel. European Journal of Technical and Natural Sciences 2024, No 3–4.* https://doi.org/10.29013/EJTNS-24-3.4-15-20

Abstract

The paper proposes an algorithm for calculating the design of a hybrid wind-solar installation. By attaching a magnet to the blades of a wind turbine, a magnetic flux is created that depends on the energy of the wind flow. If you attach a solenoid to the mast of a wind turbine, it will be possible to generate additional electrical energy. The paper proposes an algorithm for calculating wind wheels for a hybrid wind turbine.

Keywords: *Algorithm, hybrid wind turbine, generator, solenoid, generation, design*

Introduction

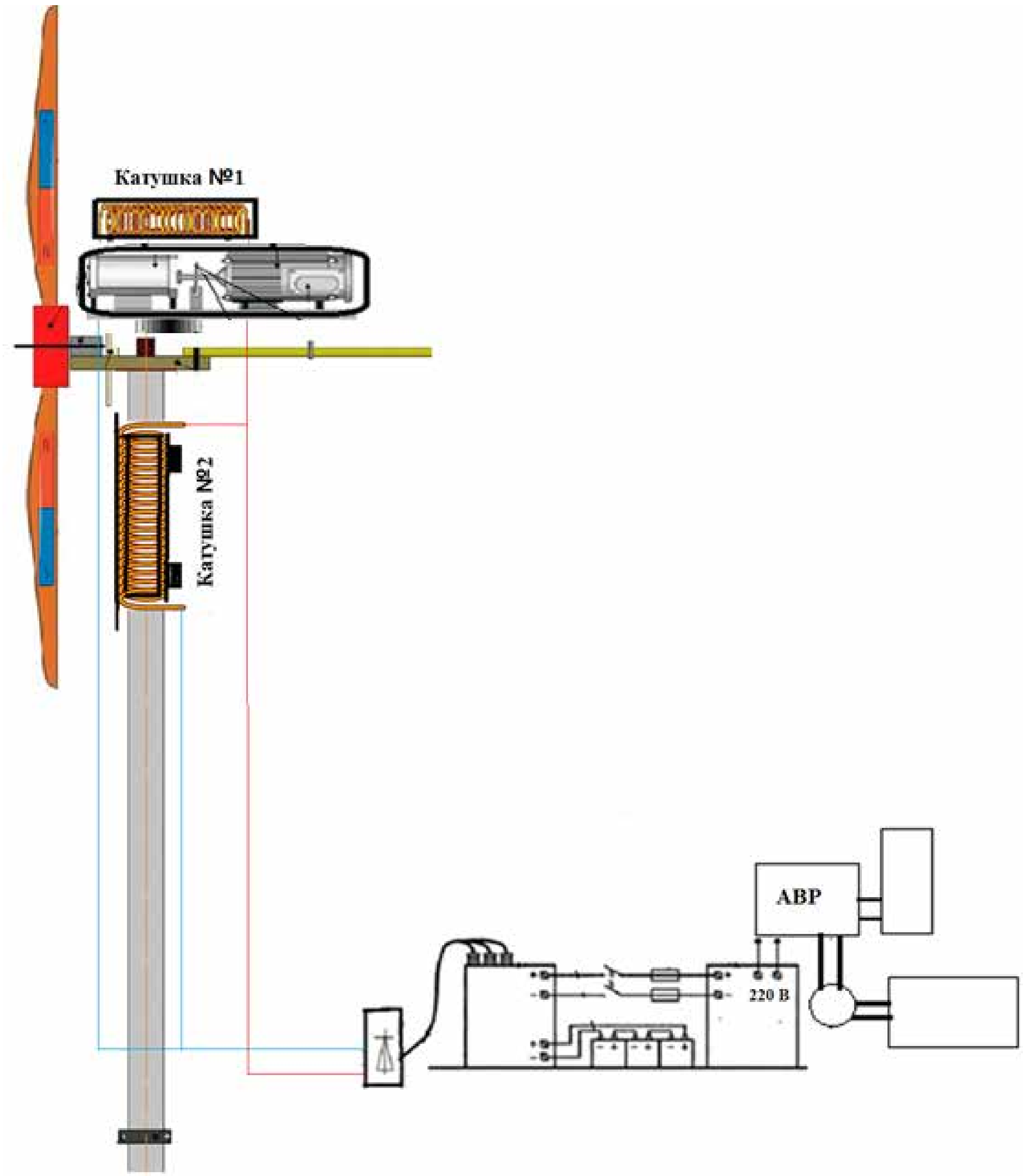
Distributed energy generation systems are hybrid energy supply systems combined from various energy sources that are built in close proximity to consumers and take into account their individual characteristics in terms of power and profile to the maximum extent possible.

One of the main generating devices of distributed generation is a wind power device. Therefore, currently, with the help of a wind energy device, it is possible to solve energy solutions for remote areas, far from the main distribution lines and places where it is impossible to install large power plants due to environmental problems. This state of affairs requires an increase in the efficiency of the wind energy device. One of the methods to increase the efficiency of a wind energy device is its hybridization.

The purpose of this work is to develop a method of hybridization of a wind energy device and an algorithm for calculating the wind wheels of this installation.

The solution method. To achieve this goal, first you need to design a hybrid wind energy device that works much more effectively than a conventional wind energy device. In (Rustamov N.T., Babakhan Sh.A., Orysbaev S.A., 2020; Rustamov N.T., Meirbekov A.T., Avezova N.R., Meirbekova O.D., Babakhan Sh.A., 2023), such a wind energy device was proposed, in which, in addition to magnetic blades on masts, Solar photopanels were constructed. Such a hybrid wind power device generates three types of current: alternating current i_1 from the generator, alternating induction current i_2 from coils attached to the masts and above the generator. Interestingly, such an installation will also generate direct current I from a Solar photopanel (Fig.1). The advantage of such a hybrid wind energy device is the efficient use of wind and solar energy.

Figure 1. *Hybrid wind power device*



The algorithm for calculating the power of a hybrid wind-solar installation

Step 1. Determination of the diameter of the wind wheel

The initial data for determining the diameter of the wind wheel are:

– rated power of the wind turbine – N_H
– estimated wind flow velocity – V_B .

When determining the required air flow power (N_P) for a wind generator of a certain power (N_H), it is necessary to take into account the efficiency coefficients of the wind wheel (η_{vk}), wind generator (η_{vg}) and transmission (gearbox) (η_t);

$$N_n = \frac{N_н}{\eta_{вк} * \eta_{вг} * \eta_т} \quad (1)$$

On the other hand, at a known speed, the power of the airflow is determined by the dependence:

$$N_n = \frac{q * W_в}{102} [kW] \quad (2)$$

where: $q = \frac{\rho * V_в^2}{2}$ – is the flow pressure (velocity head)

ρ = 0.125 kg *s²/m⁴ – air density;

$W_в = V_в * S_n$ – second flow rate (m³/s)

$S_n = \frac{\pi * d_n^2}{4}$ – the area of the airflow bounded by a circle with a diameter of – d_n:

Then, the power of the air flow, limited by a circle with a diameter of – d_n, is determined by the dependence:

$$N_n = \frac{\frac{\rho * V_в^2}{2} * V_в * \frac{\pi * d_n^2}{4}}{102} = 0.000481 * V_в^3 * d_n^2;$$

$$N_n = 0.481 * 10^{-3} * V_в^3 * d_n^2 \ [kW] \quad (3)$$

By equating the right sides of equations (1) and (3), the required diameter of the air flow can be determined:

from: $\frac{N_н}{\eta_{вк} * \eta_{вг} * \eta_т} = 0.481 * 10^{-3} * V_в^3 * d_n^2$

$$d_n = \sqrt{\frac{N_н}{0.481 * 10^{-3} * \eta_{вк} * \eta_{вг} * \eta_m * V_в^3}} \quad (4)$$

If, as a first approximation, we take:

$\eta_{вг} = 0.85; \ \eta_т = 0.94;$

that $$d_n = 51 * \sqrt{\frac{N_н}{\eta_{вк} * V_в^3}} \quad (5)$$

Note that the power developed by the wind wheel is higher, the higher its efficiency – η_{vc}

Based on static data, in the first approximation, it can be assumed: η_{vc} = 0.45; Then, the required diameter of the wind wheel equal to the diameter of the airflow can be determined by the dependence:

$$d_n = d_{вк} = 51 * \sqrt{\frac{N_н}{\eta_{вк} * V_в^3}} = 76.026 * \sqrt{\frac{N_н}{V_в^3}};$$

$$d_{вк} = 76.026 * \sqrt{\frac{N_н}{V_в^3}} \quad (6)$$

For the assumed value of the efficiency coefficient, the required power of the air flow can be determined by the dependence:

$$N_n = \frac{N_н}{\eta_{вк} * \eta_{вг} * \eta_m} \approx 2.78 * N_н;$$

Examples of calculations of the diameter of a wind wheel at different capacities of wind turbines and air flow velocities.

Table 1. *Calculation of the diameter of the wind wheel*

No.	$V_в$ m/s	$N_{вг}$ kW	$d_{вк}$ m	$N_{вг}$ kW	$d_{вк}$ m	$N_{вг}$ kW	$d_{вк}$ m	$N_{вг}$ kW	$d_{вк}$ m
1	6	2	7.34	5	11.6	10	16.4	20	23.22
2	7	2	5.8	5	9.2	10	13	20	18.42
3	8	2	4.7	5	7.5	10	10.6	20	15
4	9	2	4	5	6.3	10	8.9	20	12.6
5	10	2	3.4	5	5.4	10	7.6	20	10.8

Step 2. Estimates of the speed of rotation of the wind wheel

One of the main tasks in the design of a wind wheel is the choice of speed, which has the following dependence on speed, diameter and flow velocity:

$$Z = \frac{\omega * r_л}{V_в} = \frac{2 * \pi * n_{вк} * r_л}{60 * V_в} = 0.05236 \frac{n_{вк} * d_{вк}}{V_в}$$

where: $n_{вк}$ – the speed of rotation of the wind wheel (rpm)

$r_л$ – radius of the wind wheel blade

The speed of the wind wheel is the ratio of the circumferential speed of the end of the blade to the wind speed.

Based on experimental data, wind wheels with various $n_{вк}$, $d_{вк}$, $V_в$ it was found that the maximum value of the efficiency of the wind wheel (pvk.max) is achieved at values Z = (4...6) with the number of blades $n_л$ = = 3 pcs.

For a wind wheel with a speed of Z = 5, the rotation frequency of the wind wheel can be determined by the dependence:

$$n_{вк} = \frac{Z * V_в}{0.05236 * d_{вк}} \approx 19.1 \frac{Z * V_в}{d_{вк}} \approx 95.5 \frac{V_в}{d_{вк}} \ [\text{rpm}]$$

Examples of the calculation of $n_{вк}$ for various values of $N_н$ and $V_в$ are presented in (Table No. 2).

Table 2.

N											

$N_н$ kW	**$V_в$ m/s**	**$d_{вк}$ m**	**$n_{вк}$ rpm**	**$N_н$ kW**	**$V_в$ m/s**	**$d_{вк}$ m**	**$n_{вк}$ rpm**	**$N_н$ kW**	**$V_в$ m/s**	**$d_{вк}$ m**	**$n_{вк}$ rpm**
2	6	7.3	78	5	6	11.6	49.4	10	6	16.4	35
2	7	5.8	115.3	5	7	9.2	72.7	10	7	13	51.4
2	8	4.7	160	5	8	7.54	101	10	8	10.66	71.7

Thus, in the speed range $V_в$ = (6...8) m/s, the highest rotational speed

$n_{вк}$ =160 rpm correspond to $N_н$ = 2 kW, $V_в$ = 8 m/s, the lowest rotation speed $n_{вк}$ = = 35 rpm correspond to $N_н$ = 10 kW, $V_в$ = = 6 m/s. For the air flow velocity $V_в$ = 7 m/s for a wind generator with a power of $N_н$ = = 5 kW, the rotation frequency of the wind wheel is $n_{вк}$ = 72.7 rpm.

If we take into account that the rotation frequency of the rotor of the wind generator corresponding to the rated power is $n_{вг}$ = = (400... 600) rpm, then, for the wind wheels in question, it is necessary to use a step-up gearbox (multiplier) with a gear ratio from 5 to 10 times.

3. Step Calculation of the available power of wind power devices at a wind speed less than the calculated one.

Depending on the diameter of the wind wheel on the rated power of the wind generator;

so: $d_{вк} = 76.026 * \sqrt{\frac{N_н}{V_в^3}}$;

$$N_н = N_p^* = 0.000173 * d_{вк}^2 * V_в^3; \quad (9)$$

The rotation frequency of the wind wheel can be estimated using the formula (8).

Table 3. *Examples of calculating the available power N_p for a wind power device, with an estimated wind speed $V_в$ = 7 m/s*

$V_в$ m/s	**N_p^* kW**	**$d_{вк}$ m**	**$n_{вк}$ rpm**	**N_p^* kW**	**$d_{вк}$ m**	**$n_{вк}$ rpm**	**N_p^* kW**	**$d_{вк}$ m**	**$n_{вк}$ rpm**
7	2	5.8	115	5	9.2	72.7	10	13	51.4
6	1.25	5.8	98.8	3.16	9.2	62.3	6.3	13	44
5	0.73	5.8	82.3	1.83	9.2	52	3.65	13	36.7
4	0.37	5.8	66	0.94	9.2	41.5	1.87	13	29.4
3	0.16	5.8	49.34	0.4	9.2	31	0.79	13	22

4. Step. The algorithm for calculating the induction current.

Given the characteristics, we find the coils of the coil:

$$\omega = \frac{l_{кат}}{D_{пров}} = \frac{10 * 10^{-2}}{9 * 10^{-4}} = 1.11 * 10^2 = 111 round \quad (10)$$

1. We find the resistance of the wire wound on the coil:

$$R = \rho \frac{l_{wire}}{S} = 1.68 * 10^{-8} * \frac{17.4}{63.5 * 10^{-8}} = 0.46 [Ом] (11)$$

$$l_{1-round} = \pi * D_{coil} = 3.14 * 5 * 10^{-2} = 15.7 * 10^{-2} м (10)$$

$$l_{wire} = \omega * L_{1-round} = 111 * 15.7 * 10^{-2} = 17.4 м \quad (11)$$

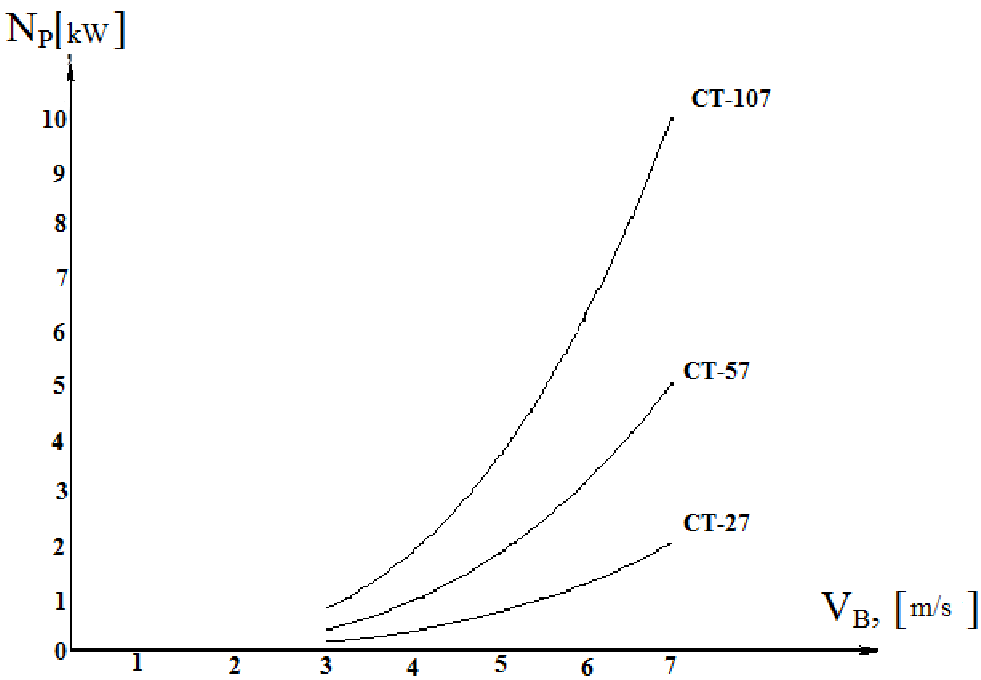
where ρ – is the resistivity of honey: $\rho = 1.68 * 10^{-8}$, l_{wire} – wire length, S – the area of the wire section

2. We find the electromagnetic flux Φ that occurs when the blade rotates with a magnet:

$$\Phi = \rho_{вз} * P_{вп} \ [wb] \quad (12)$$

here: $\rho_{вз} = 0.125 кг * \frac{c2}{м3}$ – air density;

Figure 2. *Dependence of N_p on wind speed $V_в$ for wind power devices of different rated power*



5. $P_{вп}$ it is determined from the formula (5):

$$P_{вп} = 0.481*10^{-3}*\vartheta_в^3*D_{вк}^2 = 0.015[kW] \quad (13)$$

wind speed $\vartheta_в = 5м/с$

Diameter of the wind wheel $D = 16*10^{-2}м$

6. Putting everyone in their place, we will get:

$$\Phi = \rho_{вз}*P_{вп} = 0.125*0.015 = 0.0019\,[Вб] \quad (12)$$

7. We find the electromotive force of the induction coil:

$$\varepsilon = N\frac{d\Phi}{dt} = 111*\frac{0.0019}{1} = 0.21[B] \quad (16)$$

8. With the electromotive force of induction, we find the current in the wire of the coils:

$$I = \frac{\varepsilon}{R} = \frac{0.21}{0.46} = 0.45\ [A]$$

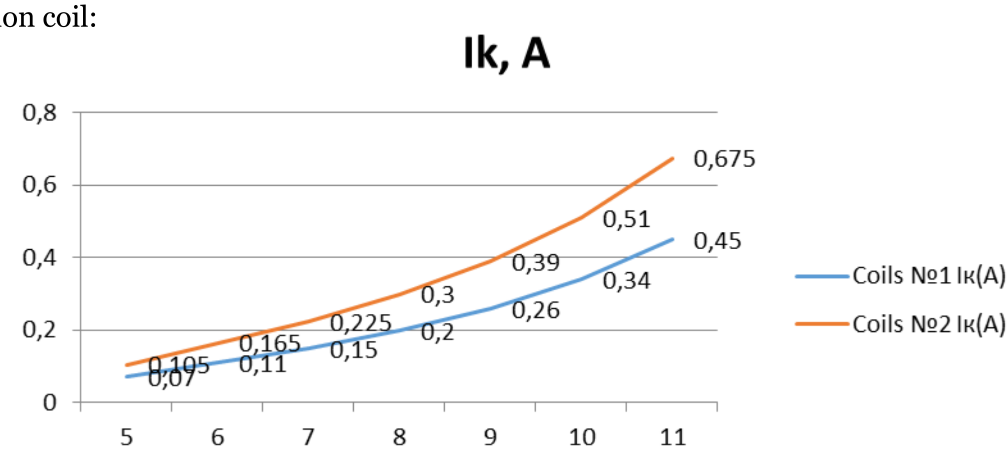


Table 4. *Comparative results of two coils*

Wind speed m/s	Coils № 1 Iк (A)	Coils № 2 Iк (A)
5	0.07	0.105
6	0.11	0.165
7	0.15	0.225
8	0.2	0.3
9	0.26	0.39

Wind speed m/s	Coils № 1 Iк (A)	Coils № 2 Iк (A)
10	0.34	0.51
11	0.45	0.675

Conclusions

The use of hybrid systems based on renewable energy sources is a promising solution for decentralized power supply in rural areas and remote facilities, as well as to ensure the accumulation of excess electric energy, removing peak loads during the operation of seasonally and weather-dependent renewable energy sources of high capacity (wind farms). Which has good coverage of the entire territory with energy networks, hybrid solutions will not be so effective. However, in connection with the long-term program of agricultural development, the construction of agro-towns, new farms, livestock complexes, hybrid technologies should be considered as an alternative to centralized energy supply.

References

Nassim Rustamov, Shokhrukh Babakhan, Naci Genc, Adylkhan Kibishov, Oksana Meirbekov. An Improved Hybrid Wind Power Plant for Small Power Generation. International Journal of Renewable Energy Research N,– Vol. 13.– No. 2.– June, 2023.– P. 629–635. (скопс Q=2)

Rustamov N. T., Egamberdiev B. E., Meirbekova O. D., Babakhan Sh. Hybrid distributed energy generation system. European Journal of Technical and Natural Sciences 1/2023.– P. 37–44.

Rustamov N. T., Meirbekov A. T., Babakhan S. A. Hybrid wind-solar power station. Patent of the Republic of Kazakhstan for utility model No. 7391 dated 19.05.2022.

Rustamov N. T., Babakhan Sh.A., Orysbaev S. A. Single-Stage Power Supply Based on Wind Turbines.– Yekaterinburg. International Scientific Research Journal, 2020.– No. 12 (102).– P. 71–75. Part 1.

Rustamov N. T., Meirbekov A. T., Avezova N. R., Meirbekova O. D., Babakhan Sh. A. Hybrid system for generating thermal and electric energy. Patent of the Republic of Kazakhstan for utility model – No. 7970.– Dated 11/24/2023.

Rustamov N. T., Meirbekov A. T., Babakhan S. A. Hybrid wind-solar power station. Patent of the Republic of Kazakhstan for utility model – No. 7391. Dated 19.05.2022.

Rustamov N. T., Egamberdiev B. E., Meirbekova O. D., Babakhan Sh., Hybrid distributed energy generation system. European Journal of Technical and Natural Sciences 1/2023.– P. 37–44.

submitted 09.05.2024;
accepted for publication 23.03.2024;
published 07.08.2024

Contact: babakhan.shokhrukh@ayu.edu.kz