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An Improved Hybrid Wind Power Plant for Small Power Generation

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Abstract- The paper proposes an improved hybrid wind power plant which is more efficient than the classical ones. The proposed hybrid wind turbine was improved by replacing the wind turbine blades with magnetic blades. The magnets are placed at the bottom of the wind vane at the design stage so as not to increase the weight of the blade. Apart from the magnetic blades, an induction coil is placed in the back of the blade. There is an air gap with a small distance between the magnetic blades and the placed coil. It is indicated that when the magnetic blades rotate, an induction current is generated on the coil. Interestingly, this creates a magnetic levitation effect that enters the stator cavity under the pressure of the wind flow. Thus, the magnetic flux penetrated into the stator space reduces the friction of the rotor. The resulting additional electrical energy in the form of an induction current increases the efficiency of the wind turbine. Further, it is argued that if solar panels are attached to the wind turbine masts, it will be possible to obtain an additional direct current. From the results of the experimental study, it was observed that the magnetic levitation application produced more energy by increasing the efficiency of the wind turbine. Thus, an important engineering task associated with increasing the long-term operation of wind turbines and effectively using the kinetic energy of the wind flow at the wind turbine.

Keywords Magnetic blades, Magnetic levitation, Wind power plant, Hybrid renewable, Distributed energy generation.

1. Introduction

With the advent of new technologies, the approach to the development of energy systems has also been changed. A distributed or small energy system can be defined as a new energy system that is provided to consumers in hard-to-reach areas, unlike traditional energy systems. When the contribution of distributed energy generation systems to the consumer is evaluated, it is an important economic contribution that these systems reduce or eliminate the electricity consumption expenses of the consumers. It also provides important contributions to the economy by meeting the energy needs of countries.

Recently, an important part of distributed energy systems are systems containing renewable energy sources, especially solar panels and wind turbines. Distributed energy generation is also an important mechanism for reducing greenhouse gas emissions. Currently, distributed energy generation technology is the only effective tool for reducing the cost of electricity for small and medium-sized businesses.

As it is known, only nearly half of the wind energy flow can be converted into electricity using wind turbines. Increasing the efficiency of wind turbines using kinetic wind energy requires a change in its design.

According to today's data, the technical indicator of wind energy in Kazakhstan is about 3 billion kWh per year. The reason for such a large energy production is explained by the fact that Kazakhstan is located in the temperate continental belt of the northern hemisphere of the planet [1]. The balance of scientific data and human experience today clearly concludes that wind turbines are not harmful to human health, in fact, wind energy reduces the amount of harmful emissions into the atmosphere and does not create any harmful production waste, compared with other sources of electricity. This conclusion was drawn from numerous independent reviews of the scientific literature.

Wind turbine projects have very short construction periods and can be deployed quickly with positive impacts delivered to local communities [2,3,4]. When the working principles of various wind turbines are analyzed within the scope of the design, the energy capacities of the wind turbines can be evaluated. There are many projects that increase the efficiency of wind turbines, in the sense of using the kinetic energy of the wind flow. If the wind turbine blades are replaced with magnetic blades and an induction coil is installed at a certain distance behind the blade, then an additional eddy current can be obtained. Thus, the efficiency of using the kinetic energy of the wind flow will increase.

As we know, the force of the wind drives the blades, which, through a special drive, make the generator rotor rotate. Due to the presence of the stator winding, mechanical energy is converted into electric current. Further, the rotational force is converted into electricity, which accumulates in the battery. The stronger the air flow, the faster the blades spin, producing more electrical energy. Since the operation of the wind turbine is based on the maximum use of an alternative energy source, one side of the blades has a rounded shape, the second is relatively flat. When the airflow passes along the rounded edge, a vacuum section is created and sucks the blade aside. At the same time, energy is created that causes the blades to rotate.

Of course, electricity is getting more expensive every year. Let's make approximate calculations and find out the prospect of reaching the payback of wind turbines, taking into account the sharp rise in the cost of electricity. At the same time, the windmill should be installed in an area with an average annual wind speed of at least 5-6 m/s. Only in these cases, the wind turbine will be a good alternative. The end result will always be the same. The energy that the wind turbine produces depends only on the area described by the blades. Let's assume that the wind turbine uses a 2KW generator. Let the cost of such a wind turbine model be about 200. But taking into account all the additional costs, you need to multiply it by two. It will turn out at least 400 units of costs, with a service life of twenty years. That is, it turns out 20 units per year. At the same time, in fact, this year the unit will give you a maximum of 900 kW. In order to somehow justify its use, the price of electricity today should reach 30 units per 1 kW. The wind should freely walk along the blades and reach them from all sides without interference. It turns out that you should live either in the steppe or near the sea (preferably directly on its shore). It turns out that the use of wind turbines in the current conditions is not entirely profitable.

The ideal location for a wind turbine, from the aerodynamic point of view, would be the top of a hill where the airflow is compressed by a corresponding increase in wind speed and pressure. Environmental factors such as precipitation and bird flock reduce the efficiency of wind turbines. Considering these important factors, we can say that such disadvantages can be compensated by replacing the wind turbine blades with magnetic materials.

As a result, it is necessary to develop systems consisting of new and renewable resources for electrical energy production, which is the basic need of all societies today. One of the most basic factors to be considered while meeting the electrical energy needs of human beings is sensitivity to the environment. For this reason, more efficient systems designed from environmentally friendly renewable resources will be priority work. In this context, the main purpose of this study is to analyze and develop a renewable hybrid system consisting of magnetic levitation wind turbine and solar panels for distributed energy generation. Although there are studies on renewable hybrid systems consisting of wind turbine and solar panels in the literature and on wind turbine-based systems with magnetic levitation, there is no study on the system proposed in this study.

2. The Proposed Hybrid Wind Power Plant

The construction of wind turbines in hard-to-reach settlements makes it possible to generate electricity in a distributed manner. At the same time, the hybridization of wind turbines is required. Such hybridization is carried out by replacing the wind turbine blades with magnetic blades, and these blades are hammered with an iron mesh. In addition, an electromagnetic coil is installed in the back of the blade at a distance. This reconstruction of the wind turbine gives us the opportunity to increase the efficiency of the wind turbine and increase the efficiency of using the kinetic energy of the wind flow [5, 6]. On the other hand, if solar panels are attached to the wind turbine mast, it will be possible to obtain an additional direct current of their solar panels. Such a system of distributed energy generation is shown in Fig.1.

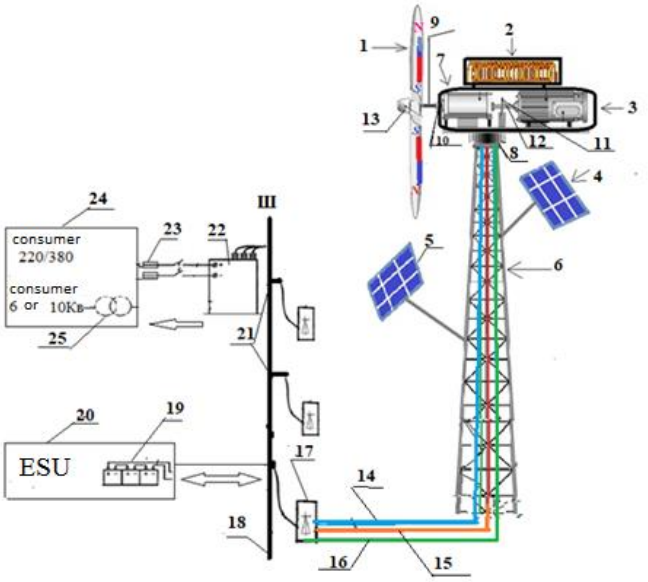

Fig 1. The schematic presentation of the proposed hybrid wind power plant.

Here: 1- blade with magnet; 2- induction coil; 3-generator; 4-5 Solar photo panels; 6-wind turbine mast; 7-gearbox; 8- yaw bearing; 9- primary shaft; 10- clutch; 11-mechanical brake; 12- generator shaft; 13- hub; 14 - i_1 current from the generator; 15- i_2 current from the magnetic coil; 16-I current from the solar photo panel; 17- rectifier; 18- DC tire;

19- batteries; 20 – energy storage unit (ESU); 21- connection points of the following hybrid wind turbines; 22, 23 - inverter with a switch; 220/380 current consumer; 25 6 or 10 kW consumer. The schematic presentation of the proposed system can be rearranged via block diagram as shown in Fig. 2.

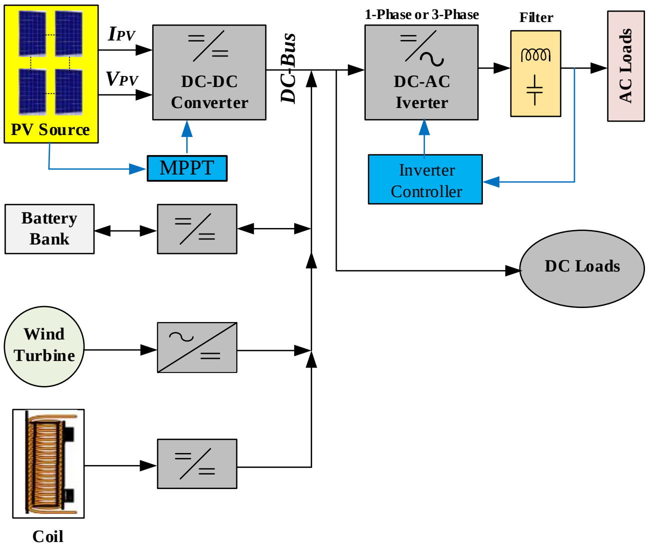

Fig 2. The block diagram of the proposed hybrid system.

The hybrid wind turbine works as follows. Under the influence of wind, the blades with magnets generating a magnetic field and generates an alternating electric current with the help of a generator. The generated magnetic field, crossing the windings of the induction coil, generates an alternating induction current. The direct current generated on solar panels is fed through the rectifier to the DC bus. Current is supplied from the bus to the inverter, using semiconductor switches, consumers can receive alternating current 220/380, or 6-10kW. Excess electrical energy accumulates in the batteries, after charging the batteries, current is supplied to the BNE unit, which has a two-way orientation. Additional hybrid wind turbines are connected to DC bus.

It is seen that the proposed hybrid wind power plant simultaneously generates three types of current. Thus, the efficiency of the wind turbine increases. On the other hand, if we use hybrid wind turbines in distributed energy generation technology, it becomes possible to provide uninterrupted electricity to consumers in hard-to-reach regions.

There may be two options for obtaining an induction current. The first option is to obtain an induction current using a coil (Fig.1), the second option is to obtain an induction current using a mesh of a clothed wind turbine blade (Fig.3). Our experiments have shown that the first option has more advantages than the second one. Below we will look at the computational models for the first option. The hybrid wind turbine shown in Fig.1 has a number of advantages from existing wind turbines. The first advantage. The magnetic field created by the blades with magnets due to the levitation effect reduces the sliding of the rotor when rotating the generator stator space, thereby increasing the service life of the wind turbine.

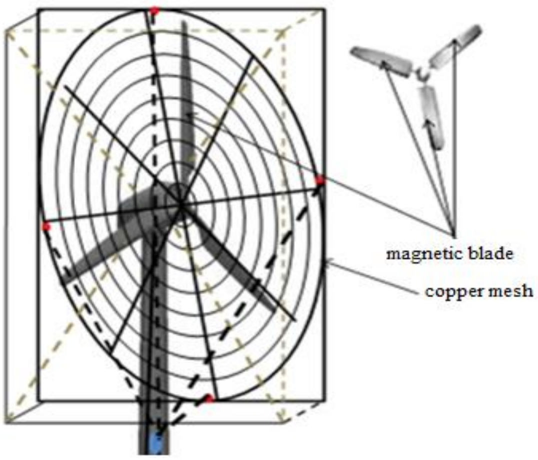

Fig 3. Blades with magnets covered with a grid.

As already noted, when a wind flow appears, a blade with a magnet of a hybrid wind turbine generates a magnetic flux *F*. The magnetic flux *F* under the pressure of the wind flow with R_{vg} energy, around the generator creates the effect of magnetic levitation [5]. Magnetic levitation is a drastic reduction of the effects of friction, sound noise, vibration and energy loss. Magnetic materials and systems are capable of attracting or repelling each other with a force depending on the magnetic field and the surface of the magnet. It follows from this that the magnetic pressure can be determined. The magnetic pressure of the magnetic field of a superconductor is calculated by equation (1).

$$P_{\text{mag}} = \frac{B^2}{2\mu_0} \tag{1}$$

where P_{mag} is the force per unit surface area in Pascal's, *B* is the magnetic induction over a superconductor in Tesla, $\mu_0 = 4\pi\times10^{-7}$ N·A^{-2} is the magnetic permeability of the vacuum. With the help of this force, the magnetic induction in $\vec{B}$ falls into the space between the stator and the rotor. As mentioned earlier, this effect is designed for stable operation of the rotor. To put the effect of magnetic levitation in front of your eyes, pay attention to Fig. 4.

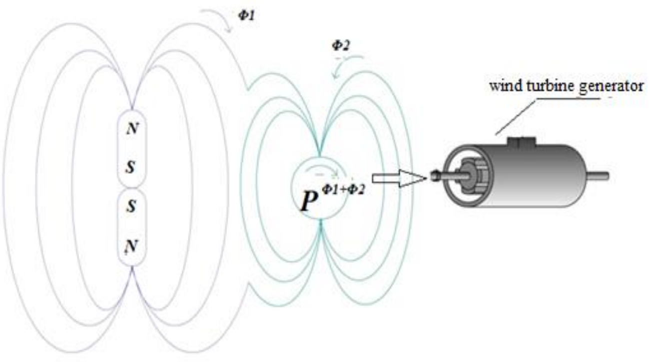

Fig 4. Generation of the magnetic levitation effect between the magnetic blades and the generator rotor [7].

From the Fig 4., Φ_1 is the magnetic flux inside the conductive grid, Φ_2 is the magnetic flux of the generator, *P* is the generator. The magnetic field inside the grid in contact with the magnetic field of the rotor creates a levitation effect, that is, an additional magnetic field $\Phi_1 + \Phi_2F$ is created in the rotor of the generator, which helps to reduce the sliding of the rotor. In turn, this leads to an easy start of the rotor, as well as long-term operation of the wind generator.

Calculation of magnetic induction $\vec{B}$ penetrating into the space between the stator and the rotor of the wind turbine generator. Before calculating, we should select the generator for the wind turbine [8-13]. The choice of generator depends on several factors. It depends on the sliding coefficient and on the electromagnetic moment of the generator. And now consider the electromagnetic moment of our wind generator. The electromagnetic moment occurs in the presence of a magnetic field generated by the stator winding and the current in the rotor winding. It is known that the electromagnetic moment of the generator is determined by the ratio;

$$M = \Phi \times I_2 \cos\varphi \tag{2}$$

where Φ is the resulting magnetic flux of magnetic levitation; $I_2 \cos\varphi$ is the active component of the rotor current; φ is the phase shift between the EMF and the rotor current, that is, $\cos\varphi = \frac{I_2}{E}$; E – EMF of the generator.

3. Design Considerations

Considering the above, the most optimal solution will be an asynchronous generator. When calculating the wind generator, we set the initial values. From the general list of the generator catalog, select AIR56A4, in which the power P = 0.12 kW, the number of rotations of the rotor n_p = 1350 rpm, current I = 0.5 A, voltage U = 240 V. In addition, V = 5 m/s (wind speed) and L = 100cm (the total length of the blades) are selected data for calculation. The magnetic induction of superconducting magnets is equal to 5 T, we decompose the magnetic induction using the fourier series equation given beow;

$$B = B_m + B_{1m}\sin\omega_1 t + \ldots.. + B_n \sin\omega_n t \tag{3}$$

where, $\omega = \frac{v}{r}$, r = 50 cm, t = 1 c, v_1 = 5 m/s, (wind speed is not constant). B_m = 5 Tl is the zero harmonic, B_{1m}= 1×5 = 5 Tl is the first harmonic, B_n is the nth harmonic. Substituting these values we can get equation (4).

$$\vec{B} = 5 + 5\sin 10^0 = 5{,}85 \text{ Tl} \tag{4}$$

This is the magnetic induction penetrating into the space between the stator and the rotor. This induction eliminates asynchronous and synchronous moments arising in the space between the rotor and the stator. Magnetic fields from higher spatial harmonics, interlocking with the rotor winding, induce EMF in it and create their own electromagnetic asynchronous moments in the motor. These moments worsen the properties of the engine, so they are called parasitic. Further, magnetic interaction forces arise between the rotating magnetic fields of the higher spatial harmonics of the stator and the rotor, which have the same order. The result of this interaction is the occurrence of a synchronous moment of the $M_{c\upsilon}$. In general, the fields of the stator and rotor from higher spatial harmonics rotate with different frequencies ($n_{\upsilon 1} \neq n_{\upsilon 2}$), and therefore the direction of the synchronous moment $M_{c\upsilon}$ varies depending on the relative position of the magnetic poles of the interacting fields. Synchronous moments in an asynchronous motor are undesirable, i.e., they are parasitic, since they can cause failures in the mechanical characteristics of the motor [5]. The influence of the relative location in space of the poles of the higher spatial harmonics of the stator and rotor fields on the direction of the synchronous moment is shown in Fig. 5.

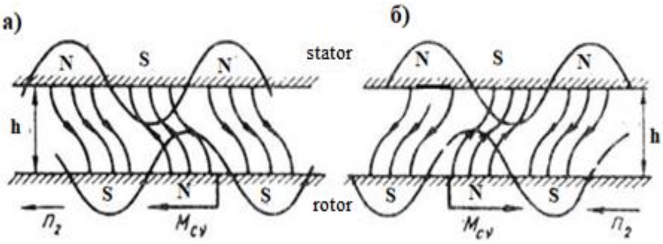

Fig 5. View of the space between the stator and the rotor.

Here a is the synchronous moment positive and b is the synchronous moment negative.

When determining the required power of the air flow (P_{af}) for a wind generator (WG) of a certain power (W_p), it is necessary to take into account the efficiency coefficients of the wind wheel (Ω_{ww}), wind generator (Ω_{wg}), magnetic coil (γ_{ml}) and transmission (gearbox) (Ω_g);

$$P_{af} = \frac{W_p}{\Omega_{ww} * \Omega_{wg} * \Omega_g * \gamma_{ml}} \tag{5}$$

On the other hand, at a known speed, the power of the air flow is determined by the dependence: [2]

$$P_{afpr} = \frac{\mu * W_p}{102} \tag{6}$$

where: $\mu = \frac{\rho_B * \vartheta_B^2}{2}$ –- flow pressure (velocity head); ρ_a = 0,125 kg*s^2/m^3– air density; $W_a = \vartheta_a * S_a$– second flow rate (m^3/s); p_b=(π*D_o^2)/4-the area of the air flow bounded by a circle with a diameter of – D_o; 102 - adjusting the air flow number. Then, the power of the air flow, bounded by a circle with a diameter of – D_o, is determined by the dependence:

$$P_{af} = \frac{\frac{\rho_a * \vartheta_a^2}{2} * \vartheta_a * \frac{\pi * D_o^2}{4}}{102} = 0{,}000481 * \vartheta_a^3 * D_o^2 ;$$

$$P_{af} = 0{,}481 * 10^{-3} * \vartheta_a^3 * D_o^2 [kW]$$

By equating the right sides of the above equations, it is possible to determine the required diameter of the air flow:

$$P_{af} = \frac{P_n}{\Omega_{vk} * \Omega_{vg} * \Omega_p * \gamma_{ml}} = 0{,}481 * 10^{-3} * \vartheta_a^3 * D_o^2 \tag{7}$$

Equation (7) will be the power model of a hybrid wind turbine (Fig.1). Using this model, you can further determine the diameter of the wind wheels as follows.

$$D_o = D_{vk} = \sqrt{\frac{P_n}{0{,}481 * 10^{-3} * \Omega_{vk} * \Omega_{vg} * \Omega_p * \gamma_{ml} * \vartheta_a^3}} \tag{8}$$

4. Results and Discussion

The experimental and calculation results of the VC diameter at different capacities of wind generators and air flow velocities are evaluated in this section. Table 1 shows the experimental results of the diameter of the wind wheels compared to power at different speed values. These experimental results are also given in Fig. 6. The electricity generation of solar photo panels is not taken into account here.

Table 1. Experimental data on the calculation of the VC diameter

ϑ_w	P_{vg}	D_{vk}	P_{vg}	D_{vk}	P_{vg}	D_{vk}	P_{vg}	D_{vk}
m/s	kW	m	kW	m	kW	m	kW	m
6	2	7,34	5	11,6	10	16,4	20	23,22
7	2	5,8	5	9,2	10	13	20	18,42
8	2	4,7	5	7,5	10	10,6	20	15
9	2	4	5	6,3	10	8,9	20	12,6
10	2	3,4	5	5,4	10	7,6	20	10,8

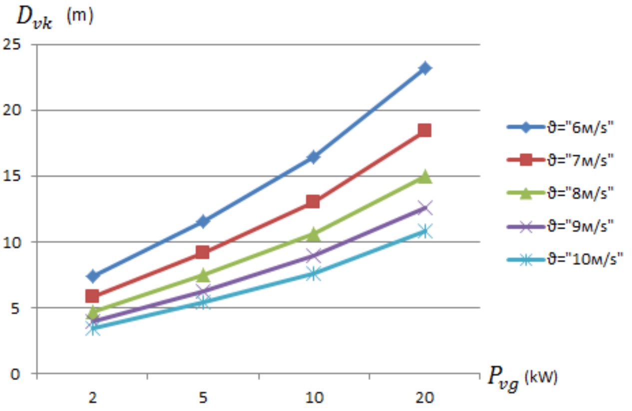

Fig 6. The diameter of the wind wheels compared to power at different speed values.

One of the main tasks in the design of VC is the choice of speed, which has the following dependence on the speed, diameter and flow rate:

$$Z_{vk} = \frac{w*R_l}{\vartheta_\text{в}} = \frac{2*\pi*\nu_{vk}*R_l}{60*\vartheta_\text{в}} = 0{,}05236\,\frac{\nu_{vk}*D_{vk}}{\vartheta_\text{в}} \qquad (9)$$

where: ν_{vk}-return of VK (rev/min); R_l-radius. For the sake of clarity Z_{vk} = 5the honor of returning BK can be determined by dependence:

$$\nu_{vk} = \frac{Z_{vk}*\vartheta_\text{в}}{0{,}05236*D_{vk}} \approx 19{,}1\,\frac{Z_{vk}*\vartheta_\text{в}}{D_{vk}} \approx 95{,}5\,\frac{\vartheta_\text{в}}{D_{vk}}\left[\frac{\text{tur}}{\text{min}}\right] \qquad (10)$$

Table 2 shows the experimental results of power, the diameter of the wind wheels and related speeds at different values. These experimental results are also given in Fig. 7 and Fig. 8.

Table 2. The experimental results of power, the diameter of the wind wheels and related speeds

P_n	$\vartheta_\text{в}$	D_{vk}	ν_{vk}	P_n	$\vartheta_\text{в}$	D_{vk}	ν_{vk}
kW	m/s	m	rpm	kW	m/s	m	rpm
2	6	7,3	78	5	6	11,6	49,4
2	7	5,8	115,3	5	7	9,2	72,7
2	8	4,7	160	5	8	7,54	101

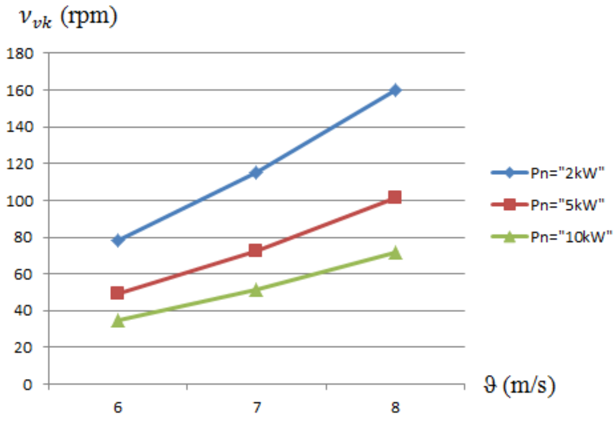

Fig 7. The results of the speed versus wind speed at different power values.

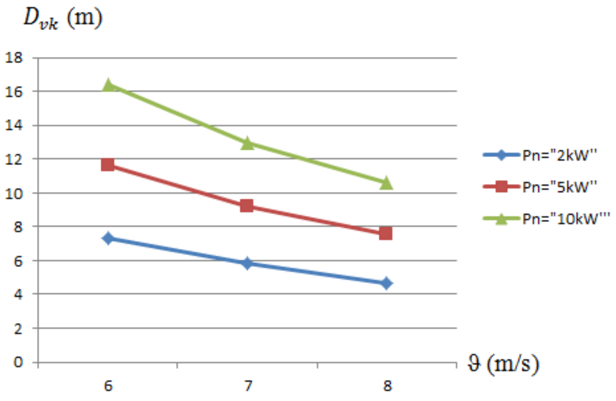

Fig 8. The results of the diameter of the wind wheels versus wind speed at different power values.

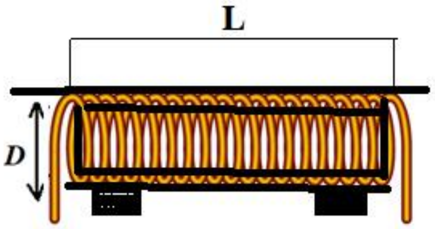

Fig 9. The used coil.

Selecting the coil (Fig.9) and the magnetic blade (Fig.1) with the following characteristics is needed for design. By selecting, $l_c = 10*10^{-2}m$, $D_c = 5*10^{-2}\,m$, $\mathrm{D}_{\boldsymbol{o}} = \mathbf{9} * 10^{-\mathbf{4}}\boldsymbol{m}$, $R_o = 4{,}5*10^{-4}m$ and $D_{vk} = 16*10^{-2}m$ we can calculate ω as follows.

$$\omega = \frac{l_c}{D_o} = \frac{10*10^{-2}}{9*10^{-4}} = 1.11*10^2 = 111round \qquad (11)$$

where D_{vc} is the diameter of the wind wheel.

$$R=\rho\frac{l_o}{S} = 1{,}68 * 10^{-8} * \frac{17{,}4}{63{,}5*10^{-8}} = 0.46\ [Om] \qquad (12)$$

$$l_{1-t} = \pi * D_c = 3{,}14 * 5 * 10^{-2} = 15{,}7 * 10^{-2} m$$
$$l_o = \omega * L_{1-t} = 111 * 15{,}7 * 10^{-2} = 17{,}4\ m$$

where p is the resistivity of honey:$\rho = 1{,}68 * 10^{-8}$, l_{provad} is the length of the wire, S is the area of the cross section of the wire. We find the electromagnetic flux F that occurs when the blade rotates with a magnet:

$$\Phi = \rho_a * P_{af} \quad [Wb] \qquad (13)$$

here : $\rho_a = 0{,}125\ \text{kg} * \frac{\text{c2}}{\text{m3}}$— air density. P_{vp} is determined from the fequation (5):

$P_{af} = 0{,}481 * 10^{-3} * \vartheta_{\text{в}}^3 * D_{vk}^2 = 0{,}015\ [\text{к}W]$ for wind speed $\vartheta_a = 5m/s$. The diameter of the wind wheel $D = 16 * 10^{-2} m$.. Putting everyone in their places, we will get:

$$\Phi = \rho_a * P_{af} = 0{,}125 * 0{,}015 = 0{,}0019 \quad [Wb]$$

find the EMF induction coil:

$$\varepsilon = N\frac{d\Phi}{dt} = 111 * \frac{0{,}0019}{1} = 0{,}21\ [V]$$

with EMF induction, we find the current in the wire of the coils:

$$I = \frac{\varepsilon}{R} = \frac{0{,}21}{0.46} = 0{,}45[\text{A}]$$

This will be the current generated by the coil when the blade with the magnet rotates at a speed of 5 m/s. This current will contribute the additional electricity to the hybrid system. The third advantage of the system is the current generated by solar panels attached to the masts of a hybrid wind turbine (Fig.1). Let's calculate how much electric power these solar panels generate.

Assume that 12 solar photo panels are attached to the mast of a hybrid wind turbine. Let's the solar panels has following nominal values.

Maximum power: 110W

Dimensions: 1,2x0,67

S=10 m^2

S of one = 1.2 x 0.67=0.84 m^2

Number of panels per 10m^2: $N = \frac{S_g}{S_o} = \frac{10\ m^2}{0{,}84\ m^2} = 12$ pieces

Total battery power: 110x12 = 1320 W;

Calculation of the coefficient of solar insolation, i.e., the number of peak hours is taken from the table of monthly and annual amounts of total solar radiation, kWh/ m^2. Such tables exist for each region [14, 15]. There are a lot of studies in the literature related to obtain maximum power from solar system and solar panel design [16-18]. To calculate the peak hour coefficient, we attached solar panels to the masts at an angle of 50.0 degrees, at a latitude of 43.1 degrees. Each solar panel is attached according to obtain maximum power in lower area. We divide the annual value of the total solar radiation by the number of days in a year, we get the average total value for the day. The resulting value is divided by 1000, and we get a conditional time during which the sun shines as if with an intensity of 1000 W/m^2. *1681 kWh/m2/ 365 = 4,6 kWh/m2;* $4{,}6\text{kWh/m2} \div 1000\text{W/m2} = 4{,}65\text{kWh/m2} \cdot \frac{\text{m}^2}{\text{kWh}} =$ 4,6 hour. Taking into account the fact that the sundial per day is equal to 4.6, we calculate the electricity generated per day: 1320x4.6 = 6072 W * h; Electricity generated per month: 6072x30 =182160 W*h; Electricity generated per year: 182160x12 = 2185920 W*h = 2186 kWh. Since the total power of the panel is 110x12 = 1320 watts.

For example, to calculate the peak-hour coefficient, we attach solar panels to the wind turbine masts at an angle of 50.0 degrees, at a latitude of 43.1 degrees. By dividing the annual value of the total solar radiation by the number of days in a year, we can get the average total value for the day. The resulting value is divided by 1000, and we can get a conditional time during which the sun shines as if with an intensity of 1000 W / m^2. 1681 kWh/m2 / 365 = 4,6 kWh/m2; $4{,}6\text{kWh/m2} \div 1000\text{kW/m2} = 4{,}65\text{kWh/m2} \cdot \frac{\text{m}^2}{\text{kWh}} \approx 4{,}6$ hour. Taking into account the fact that the sundial per day is equal to 4.6, we calculate the electricity generated per day as 1320x4.6 ≈6072 W * h. If we install these panels on the wind turbine masts, then this power is generated approximately on an area of 1m^2. This increases the efficiency of hybrid wind turbines.

5. Conclusion

An improved hybrid photovoltaic panel added wind power plant which was improved by replacing the wind turbine blades with magnetic blades was proposed in this study. The magnets are placed at the bottom of the wind vane at the design stage so as not to increase the weight of the blade. Apart from the magnetic blades, an induction coil was placed in the back of the blade. The magnetic flux created by the blades of the wind generator has the double advantage, firstly it produces an induction current on the coil, secondly it prolongs the service life of the wind turbine due to levitation in the stator cavity. Magnetic levitation produced by magnetic flux due to torsion of the blades is used to extend the service life of the wind turbine.

Wind power plants are very safe and very healthy. We can safely say that the generating capacity of wind energy is very amazing. In order to increase the service life and effectively use the kinetic energy of the wind flow, the proposed hybrid wind turbine with magnetic blades has shown its efficiency in practice. On the other hand, the proposed system of distributed energy generation based on hybrid wind turbines can be used in hard-to-reach regions.

The experimental results of the diameter of the wind wheels compared to different power values at different speed values were presented in the study. The calculations made on magnetic levitation and the experiments carried out on the model installation showed the objectivity of the proposed concept for extending the service life of wind turbines using magnetic levitation. On the other hand, with the help of solar panels attached to the experiment, it was shown that with such technology it is possible to generate additional electrical energy.

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