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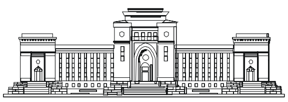

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EFFICIENCY IMPROVEMENT OF SELF-REGULATING WIND POWER PLANTS

Abstract. The wind power plant with high coefficients of use in time and rated power has been Developed. It operates in the range of wind speeds from 2-3 to 50 m/s. The rated power is achieved depending on the design at speeds from 5-8 m/s to 50 m/s.

Key words: self-regulating wind power plant, coefficient of use in time, coefficient of use of nominal power.

Introduction. The WSEC-2017 Congress of Scientists and Engineers "Energy of the Future: Innovative Scenarios and methods for their implementation" within the framework of the international exhibition EXPO-2017 on June 19-20 in Astana confirmed the relevance of using wind power plants (WPP), solar battery and recognized this direction as very promising [1, 6 - 16]. However, the use factors of the nominal power and the use of WPPs in time are not at a sufficiently high level, which does not allow to reduce the cost of generated electricity to the cost of energy from grid networks. In addition, there are environmental problems.

At the same time, there are already a number of technical solutions [2], providing a significant reduction in energy costs due to the fact that the WPP nominal power is achieved at lower wind speeds compared to traditional installations, and the operating time during the year increases significantly, environmental problems are also excluded.

This is achieved by increasing or decreasing the swept area by changing the blades position [3].

Figure 1 – "Torus" Wind Power Plant

In Figure 1, one of the variants of WPP [3] is shown. It allows to change the swept area depending on the wind speed.

The installation works as follows. Wind flow enters the blades, which leads to their rotation on the shaft. With increasing wind speed due to wind pressure, the blades begin to interlock. In case of hurricane gusts of wind, the blades close completely and take the form of a torus.

It should be noted that when the blades close, as field tests showed, the WPP continues to work and in practice successfully operated at a wind speed of 50 m/s.

The reasons for operation at high wind speeds are as follows. When the blades close, the wind resistance decreases, the blades begin to open, but because of the strong wind, the blades again close and continue to rotate.

By increasing the wind speed the swept area decreases due to the closing of the blades, a rational number of blades can be justified by the need to increase the swept area with the same torus diameter.

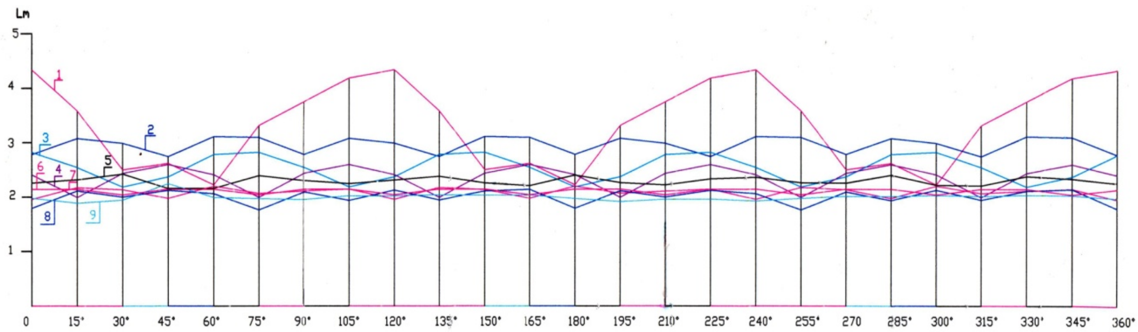
A smaller number of blades causes a larger diameter in the open position, i.e. at a low wind speed. The maximum diameter is obtained with two blades, when the diameter of the torus is divided in half. But in this case, as shown by experiments with WPP built in accordance with the patent [4] (Figure 2), WPP works in spurts with a diameter of more than 50 cm and uncontrolled locking of the blades takes place.

Figure 2 – M.M. Mailybayev Wind Power Plant

By increasing the number of blades [3] from 3 or more, there is a change in the swept area depending on the rotation to the wind direction as shown in Figure 3. As can be seen, a smoother change in swept area begins with 4 blades and more.

The amount of labor for the manufacture of blades and the number of bearings for the blades rotation is directly proportional to their number.

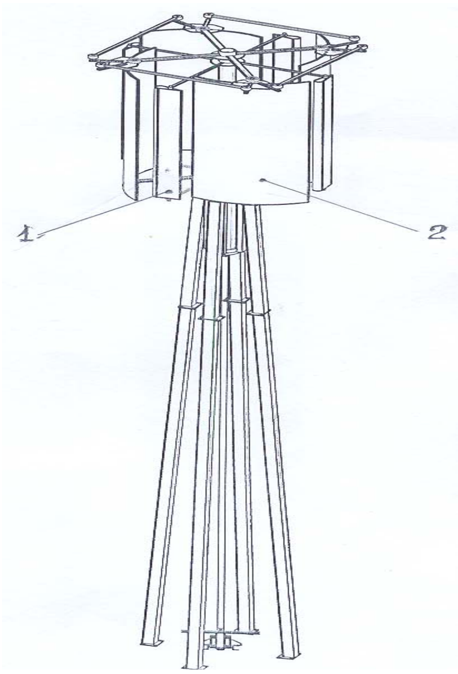
In addition, a smaller number of blades accounts for a large area of the swept area with the same diameter of the closed position of the WPP blades. In this regard, 4-blade WPP is considered.



1 – three blades; 2 – four blades; 3 – five blades; 4 – six blades; 5 – seven blades; 6 – eight blades; 7 – nine blades; 8 – ten blades; 9 – eleven blades

Figure 3- Swept Area Change Graph depending on the rotation angle of the blades for their different amount

Known methods for determining the reaction forces of articulated joints can be used to engineer wind power stations, therefore it is possible to develop design documentation for wind power stations of various capacities [17]. It should be noted that sailing blades are most effective at low wind speeds and inferior to aerodynamic ones at wind speeds of more than 10-12 m/s. At the same time, traditional WPPs with aerodynamic blades do not operate at wind speeds of more than 25 m/s in order to avoid the destruction of WPPs. Considering the above-given, an increase in the utilization rate of nominal power and the use factor of WPP in time with maximum efficiency is possible by combining self-regulating sailing and aerodynamic blades [5] (Figure 4).



1 - aerodynamic blades, 2 – sailing blades.

Figure 4 – Wind Power Plant with combined sailing and aerodynamic blades

With a wind speed of up to 10 m/s, mainly sailing blades work, and aerodynamic ones do not have a significant effect on WPP operation. With an increase in wind speed, sailing blades shelter themselves behind, aerodynamic blades begin to work more intensively. With a wind speed of more than 20-25 m/s, sailing blades close completely, but continue to rotate the generator, and the aerodynamic blades go into braking mode by way of turning.

In order to reduce the resistance to the wind pressure of sailing blades during their movement against the wind, they are made in the form of segments of the hollow torus, similar to Figure 1.

It should be noted that in any design, the wind entering the working part of the sailing blade, having given up part of the energy, enters the working part of the blades, which move against the wind direction, thereby continuing to perform useful work. Comparative characteristics and parameters of well-known wind power plants, as well as the developed options are shown in Table 1 [2].

As can be seen, for various WPP options, the rated power is achieved at low wind speeds, and the WPP use factor is significantly increased in time.

In general, the main parameters affecting the cost of energy are the use ratio of the nominal power, the use ratio in time and the efficiency ratio (ER).

Practically, the efficiency ratio for each particular design of the blades is constant, and the use ratio in time and nominal power are variable and depend on many factors. For example, for vertically axial WPPs, the use ratio in time is significantly higher than for horizontally axial ones, since the latter require turning to the wind, and the turn occurs after the WPP stops operating. At the same time, in the wind corridors, the indicated ratio of vertically axial and horizontally axial wind power plants becomes very close.

Table 1 - The main parameters of traditional and proposed wind power plants

Indicators	Parameters	
	Traditional wind power plants	Proposed wind power plants
Working range of wind speeds, m/s	from 3-4 to 25	from 3 to 50
Rated power at wind speed, m/s	from 10-12 to 25	from 8 to 50 from 5 to 50
Minimum efficiency at wind speed, m/s	to 10-12	to 5
Maximum efficiency at wind speed, m/s	from 10-12 to 25	from 8 to 50 from 5 to 50*
Amount of working time per year, hour	2500 – 3000, 10% to 5000	to 6000-7000
Time use factor	0,28 – 0,34 and 10% to 0,57	0,68-0,8
Efficiency factor	Theoretical 0,45 Actual ≤0,38	0,24** 0,4-0,45
Average annual utilization rate of rated power	Depending on region ≤0,3	Non-depending on region 0,6
Maximum speed of rotation of the wind wheel, revolutions per minute	To 500	15-20
Electricity cost, €/kW·hour	0,15	0,04
Ecological aspect	The presence of infrasound, as well as in the acoustic range	There is no infrasound, vibration and noise; not dangerous in the way of bird migration, environmentally friendly

* Increasing the parameters of the blades to achieve the rated power at a wind speed of 5 m/s is possible without compromising the reliability of the electromechanical part and the wind power plant as a whole, due to the fact that the blades interlock with increasing wind speed, reducing the swept area. The wind at a speed of 5 m/s per year is much more frequent than at a speed of 10-12 m/s.

** Efficiency ratio is not that important, because there is no charge for the wind, but it requires an increase in the swept area due to changes in the blades parameters.

The power factor for known WPP designs functionally depends on wind speed. Typically, the rated power is achieved at wind speeds of 10-13 m/s and up to 25 m/s. Achieving the rated power at low wind speeds causes an increase in the parameters of the blades, which can lead to emergency situations with an increase in speed, namely: failure of electrical equipment or failure of the blades. In this regard, the increase in the parameters of the blades of traditional WPPs is not practiced.

Conclusions: Unlike traditional WPP, the proposed design allows to increase the parameters of the blades, since as the wind speed increases, the blades interlock under its pressure, reducing the swept area. Consequently, the nominal power achieved at low wind speeds is preserved, as practice has shown, even at wind speeds of up to 50 m/s. In addition, one can use confusors, which increases the wind speed to achieve the nominal power at a lower speed, and with increasing speed the WPP destruction does not occur due to the interlock of the blades.

The ability to change the swept area also has a positive effect on the WPP use ratio over time, namely, the number of working hours per year with the rated power increases, since the design of the proposed WPP allows working from 2-3 m/s to 50 m/s.

The combination of sailing and aerodynamic blades maximizes efficiency ratio, while taking advantage of sailing blades to work effectively at low wind speeds, and at medium speeds - the advantages of aerodynamic blades. As noted above, when hurricane speeds the sailing blades interlock, and the aerodynamic enter the braking mode, while the WPP continues to generate electricity up to a wind speed of 50 m/s.

Thus, due to the given competitive advantages, as shown by the calculation, the proposed design of WPPs allows to reduce the cost of energy to the level of energy cost on electric grid networks.

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ӨЗДІГІНЕН РЕТТЕЛЕТІН ЖЕЛ ЭЛЕКТР СТАНЦИЯЛАРЫНЫҢ ТИІМДІЛІГІН АРТТЫРУ

Аннотация. Жел қондырғысы уақыт пен номиналды қуаттың жоғары пайдаланылуымен дамыды. Желдің жылдамдығы 2-3-тен 50 м/с-ға дейін жұмыс істейді. Бұл жағдайда номиналды қуат дизайнға байланысты 5-8 м/с-тан және 50 м/с-ға дейінгі жылдамдықта қол жеткізіледі.

Түйін сөздер: өздігінен реттелетін жел элетр станциясы, уақыт бойынша пайдалану нормасы, номиналды қуатты пайдалану деңгейі.

УДК 621.311.24

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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ САМОРЕГУЛИРУЮЩЕЙСЯ ВЕТРОЭЛЕКТРОСТАНЦИИ

Аннотация. Разработана ветроэлектростанция с высокими коэффициентами использования во времени и номинальной мощности. Работает в диапазоне скоростей ветра от 2-3 и до 50 м/с. При этом номинальная мощность достигается при скоростях от 5-8 м/с и до 50 м/с в зависимости от конструкции.

Ключевые слова: саморегулирующаяся ветроэлектростанция, коэффициент использования во времени, коэффициент использования номинальной мощности.

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