DYNAMIC BALANCE AND WEAR CONDITIONS OF AN CONIC WIND TURBINE WITH AN INCLINED AXIS

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Abstract

A new type of wind turbine with inclined axis is proposed, which is radically different from all so far known wind generators of two main types (with horizontal and vertical axes) and contains an electric generator with a wind turbine with vanes, envelopes a conical surface during rotation, one generatrix of which is horizontal (with the lower arrangement), and its opposite — vertical (with the top arrangement). The force of friction is calculated and the angle of the sector of contact as friction zone of the sleeve slider with the wind turbine shaft is determined.

Key words: wind turbine, inclined axis, electric generator, vanes, slider, friction zone.

Introduction

Having its own power station on the roof of the house means to generate electricity for the family for free, which is a tempting prospect for a broad consumer market. The positive sides of using wind power:

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- Reduces dependence on imported organic fuels;
- Increases the level of energy security;
- Cheap (after the recoil period);
- Creates competition on the energy products.

Although modern technology of using wind energy also has negative aspects, which greatly hinders its widespread use:

- A wind power station requires a large area;
- Creates a threat to migratory birds;
- Generates vibration and noise.

Two main types of wind turbines are widely distributed: With vanes rotating in a vertical plane around the horizontal axis and with vanes vertically mounted on the vertical axis of rotation with their cylindrical arrangement. Wind turbines of these types relatively each other have some advantages and accordingly – also disadvantages. In particular, the vanes, vertically cylindrically located around the vertical axis, do not needs of special facilities for direction they're on the wind, but because of the cantilever attachment, from them on the base high loads are transferred.

With respect to the foregoing, it is may to better use wind energy by turbine with vanes arranged around a horizontal axis in a vertical plane, but they need the location of power plants (electric generators) exceeding the radius of the wind turbine and therefore it is dangerous to place them on the roofs of houses.

The proposed product is targeted on the optimal using of unused today areas (roofs of houses), what can be achieved through of the unique design of the new wind turbine, in particular – as a result of a sharp reduction in vibration.

The main advantage of our approach is the wind power converter designed mostly for inexpert consumer, which will be equipped with the aircraft's tail blade-like wind vane (eg, the planer), that is, the creation of the most ecological, energy saving and safe mass-consumption wind motor, and

equipping it with a simple automatic control mechanism (with 4th degree of kinematic freedom) and/or a microcontroller (with 6th degree of kinematic freedom); as a result, new products will be produced, whose wind turbines will be optimally directed to the oncoming air flows that will increase its rotational speed and efficiency of wind power consumption. In addition, the kinematics of the wind rotary axis base, in particular the double hinged connection with a base, leads to the spatial kinematic pliancy of a new wind motor in the horizontal and vertical planes, while its flexible units bring dynamic pliancy in line with variable loads. Finally, as a result of the minimization of dynamic loads, almost the entire static load caused by the used wind power reactive forces is actually transferred to the support - with a minimal dynamic component.

Problem's Solving

A new type of currently-unknown wind turbine is proposed (Figure 1) which differs radically from the still known wind turbines of two main types (with horizontal and vertical axes) and contains an electric generator 1 cinematically connected to a wind turbine 2 with vanes 4 that are radially disposed in equal intervals and pivotally connected to the hub 3; the vanes, when rotating, envelope a conical surface, one of which is horizontal (with a lower location), while its opposite generatrix is vertical (with an upper arrangement). The vanes 4 are connected to the hub 3 by hinges, with the possibility of angular movements their ends along the radial surfaces into the inner volume of the circumscribed conical cone, and along the inner side of said cone together with coaxial spring inserted a slider located on the rotation axis 5 of wind turbine 2 between its end and the hub, wherein a slider 15 is connected to using arms 17 by hinges 16 to the vanes 4. On the axis of the wind turbine, near the electric generator accomplished a stop-element, between which and of the rotational support of the axis a coaxial spring 18 is inserted (to ensure pliancy of vanes 4 with the reserve of obliquity right angle $- 0 \leq 90^0$). At the same time, a splined connection can be made between the electric generator and the axis of the wind turbine, or - the connection between the electric generator 1 and the axis 5 of the wind turbine 2 can be made rigid, but the electric generator 1 itself can have ability of movement in the guides 22 along the support 21.
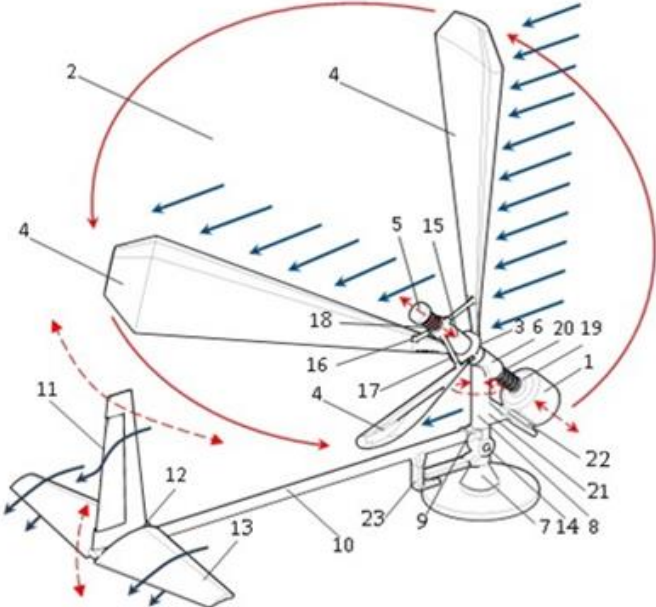

Figure 1. Wind turbine scheme.

In addition, the rotation support of the wind turbine in turn, is mounted on a vertical rotation support 8 placed on the base, while by means of adjusting hinge 9, a wind vane 11 is connected to it rigidly to it, which has an aircraft blade-like shape 13 which has connected hingedly 12 to it, while a vertical rotation support 8 is connected to a base 7 by means of a transverse horizontal hinge 14, and the wind vane 11 has base has an elastic connection 23 with a base 7 (variable movements are shown in intermittent red arrows). Wind flows (shown in blue solid arrows) set in motion the wind turbine 2

with vanes 4 that are radially disposed in equal intervals on the hub 3, by means of them, it rotates the axis of an electric generator 1 (shown in arc-like arrows).

Has been develop theoretical basis and technological solutions that leads to creation of the ecological, energy-saving and safe mass-consumption wind motor equipped with a simple automatic control mechanism, which will successfully replace the same-purpose existing expensive, wide-consumption analogue, in particular, the dangerous articles (as the source of excessive vibrations), and will significantly improve not only the use of renewable energy sources but also environmental conditions.

Methodology

During the research the method of system analysis is used. In theoretical research, the mathematical modelling and calculation of the object is carried out taking into consideration the physical similarity criteria.

Identification and comparative analysis of numerical values of the results of simulation modelling and practical experiments (laboratory and production tests) will be carried out in a computer (virtual) environment using mathematical statistics.

Discussion

Settlement dynamic system is carried out for a new type of conic turbine wind motor with inclined axis for provision its of spatial equilibrium and dynamical balance. On a cinematic schemes provided the settlement dynamic system with four rotating mass of shaft and rotor of the electric generator, also of inertial mass of wind-vane (with fuselage) and same electric generator.
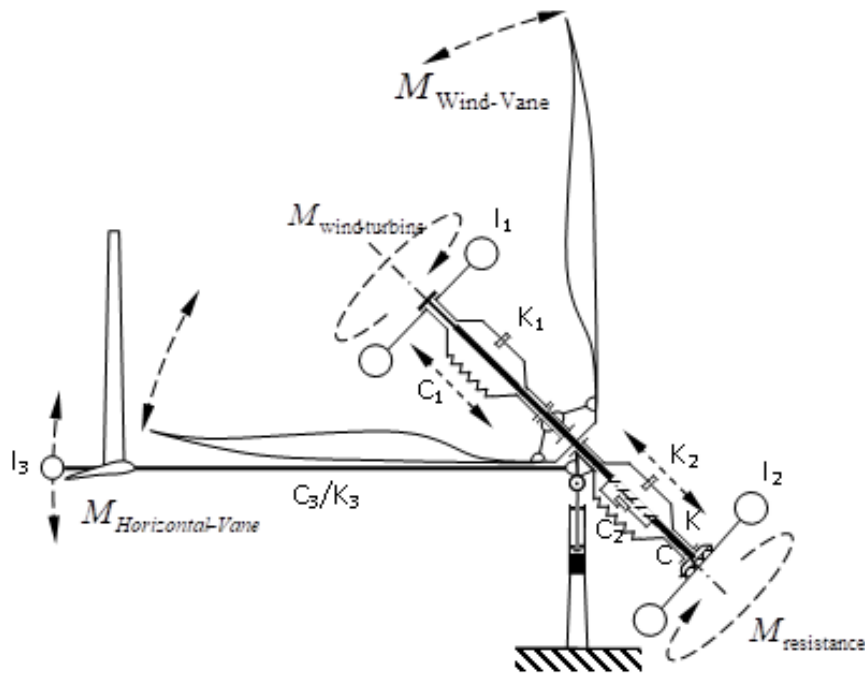

Figure 2. Kinematical scheme of calculating dynamic system of wind motor, where: $M_{Wind-Turbine}$ - wind turbine's torque; $M_{Resistance}$ - moment of induction resistance created by the magnetic field of the generator when converting rotation into electricity; $M_{Horizontal-Vane}$ - moment of resistance of the adjustment rod like the tail of an airplane (the fuselage), when the vanes of the wind turbine forces to incline over; I_1 - inertial moment of wind turbine's rotating masses; $M_{Wind-Wane}$ - moment of force pressing of the Wind-turbine vanes on the adjustment rod like the tail of an airplane (the fuselage) by rod arms; I_2 - inertial moment of electric generator's rotating masses; I_3 - moment of inertia of the masses of the fuselage and the weather vane during arc oscillations; I_4 - moment of inertia of the masses of the generator during arc oscillations; C, K - respectively, torsional rigidity and damping coefficients of wind turbine's inclined axis; C_1, K_1 - respectively, coefficients of wind turbine rigidity and damping of thrust spring on slider of the inclined axis; C_2, K_2 - respectively, coefficients of rigidity and damping of thrust spring of electric generator on the inclined axis.

The dynamic system circuit branches out as power flows. The following conditions are fulfilled on them: the mass of the wind turbine, its axis, rocker arms and slider are brought at one inertia moment; The elastic bands of the wind turbine wings in a circular direction are ignored and brought at one inertial moment, and in the radial direction they are described by the linear movement of the slider; The elastic interactions of kinematic pairs are continuous; The deflection of the armature of the electric generator is zero in a circular direction; The equilibrium equations of the oscillatory system according kinematical scheme (Figure 2) for calculating of dynamic loads, obtained under these conditions, are written as follows:

$$I_1\ddot{\varphi}_1 = M_{\text{wind-turbine}}(t) - C \cdot (\varphi_1 - \varphi_2) - K \cdot (\dot{\varphi}_1 - \dot{\varphi}_2)$$
$$I_2\ddot{\varphi}_2 = C \cdot (\varphi_1 - \varphi_2) + K \cdot (\dot{\varphi}_1 - \dot{\varphi}_2) - M_{\text{resistance}}(t)$$
$$I_3\ddot{\varphi}_3 = M_{\text{Wind-Vane}}(t) - C_V (\varphi_3 - \varphi_4) - K_V (\dot{\varphi}_3 - \dot{\varphi}_4)$$
$$I_4\ddot{\varphi}_4 = C_V (\varphi_3 - \varphi_4) + K_V (\dot{\varphi}_3 - \dot{\varphi}_4) - M_{Horizontal\text{-}Vane}(t) \qquad (1)$$
$$m_1\ddot{x}_1 = F_{wind-Vane}(t) \cdot \cos\alpha - C_1 \cdot (x_1 - x_2) - K_1(\dot{x}_1 - \dot{x}_2)$$
$$m_2\ddot{x}_2 = C_2 \cdot (x_1 - x_2) + K_2(\dot{x}_1 - \dot{x}_2) - F_{\text{resistance}}(t)$$

As a result of the flexibility of the structure, the oscillations ($I_1\ddot{\varphi}_1$ and $I_2\ddot{\varphi}_2$) of the rotating masses, will be minimized, which reduces the dynamic loads on the shafts and increases their durability, which allows us to use into account the simplified kinematic scheme (Fig. 3) and the system of equations (2):

$$I_3\ddot{\varphi}_3 = M_{wind-Vane}(t) - C_V (\varphi_3 - \varphi_4) - K_V (\dot{\varphi}_3 - \dot{\varphi}_4)$$
$$I_4\ddot{\varphi}_4 = C_V (\varphi_3 - \varphi_4) + K_V (\dot{\varphi}_3 - \dot{\varphi}_4) - M_{Horisontal\text{-}Vane}(t)$$
$$m_1\ddot{x}_1 = F_{wind-Vane}(t) \cdot \cos\alpha - C_x \cdot (x_1 - x_2) - K_x(\dot{x}_1 - \dot{x}_2) \qquad (2)$$
$$m_2\ddot{x}_2 = C_x \cdot (x_1 - x_2) + K_x(\dot{x}_1 - \dot{x}_2) - F_{\text{resistance}}(t)$$
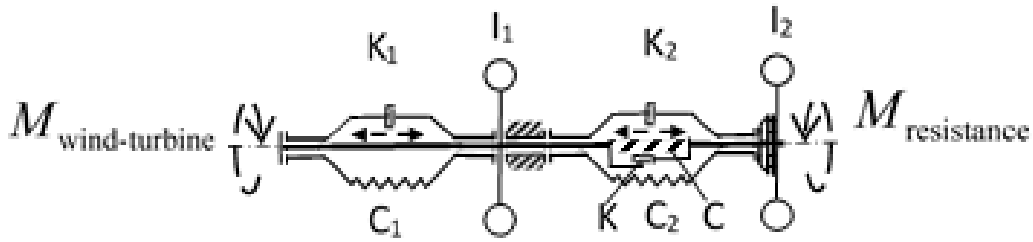

Figure 3. Simplified kinematical scheme of calculating dynamic system of wind motor.

For the tribological task, the high friction resistance of the wing of the wind turbine on the adjustment rod, where is considered as the sum of dry and viscous frictions forces (Fig. 4), is of interest. The friction of force is equal to the production of the sliding friction coefficient by the support reaction force and is calculated by the formula:

$$F_{\text{resistance}}(t) = f \cdot N + \mu \cdot U^2 = F_f + F_u \qquad (3)$$

Where, F_f - Dry frictions resistance force; F_u - Viscous frictions (lubricating material's) resistance force; N - Normal (perpendicular directed) force; f - Dry frictions coefficient; U - Speed of the slider; μ - Viscous frictions coefficient.
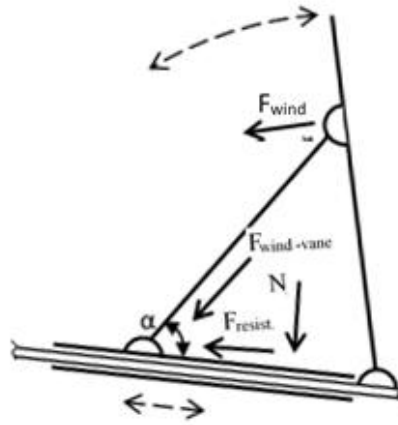
Figure 4. The scheme of dry and viscous frictions forces.

The contact zone angle (φ) of the sleeve slider with the wind turbine's shaft (Fig. 5), determined by the formula:

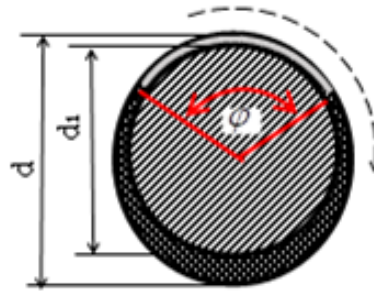$$\varphi = \frac{360^0 \cdot \pi d b}{\Delta d - b} \tag{4}$$

Figure 5. The contact zone angle (φ) of the sleeve slider with the wind turbine's shaft (d – diameter of sleeve; d_1 – diameter of shaft).

The choice of lubricant characteristics depends on the angle (φ) of the contact zone.

5. CONCLUSIONS

The environmental, energy-saving and safe wind motor equipped with automatic control mechanism, allows for its mass consumption, in particular, due to the compactness, it cause no threat to migratory birds, and most importantly, does not generate vibrations the support base, which is positive factor when installing on a high-rise residential building.

The proposed product is oriented towards the optimal use of residential buildings' roofs, which is achieved due to the unique design peculiarities of a newly-invented wind motor - in particular, due to its compactness, control flexibility and sharp reduction of vibrations. These advantages and positive sides of wind power will significantly increase the wide range customers' demand in the private sector and will make it as object of massproduction.

The following challenges may arise during the device implementation: the aircraft's tailwing-like wind vane of should provide a turnaround in the upwind direction. These conditions the optimal selection of the parameters (of the vertical or horizontal wing-shape and its turning mechanism) and high reliability of the functioning of microcontroller providing the automatic control, which should be entirely possible during the of device implementation.

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