

Combined Mechanical Systems of Anti-Storm Protection of Horizontal-Axis Wind Turbines

Vitaliy Korendiy, Vitaliy Vergeles

Department of Mechanics and Automation in Mechanical Engineering, Lviv Polytechnic National University, UKRAINE, Lviv, S. Bandery street 12, E-mail: vitaliy.nulp@gmail.com

Abstract – The necessity of further improving of existent regulation mechanisms is motivated for the purpose of increasing of accuracy of power regulation, effectiveness and reliability of wind turbines functioning in wide range of wind speeds. The prospects of creation of combined mechanical systems are considered, where the possibilities of simultaneous blades turning and folding, blades turning (or folding) and wind-wheel deflection out of wind direction are provided.

Key words – wind turbine, anti-storm protection, mechanical system, power regulation, rotation frequency stabilization, blades turning mechanism, blades folding mechanism.

I. Introduction

Real independence of any country substantially depends on the state of its fuel and energy complex. As far as Ukraine is concerned, permanently increasing of electrical energy deficiency, depletion of environmental resources of organic fuels, ecological problems of nuclear and thermal (heat) power plants cause the arising of the chain of essential problems in its fuel and energy complex. Analyzing the experience of advanced countries, obviously, the priority in this problem is given to the application of power-saving technologies and alternative energy sources. And at the same time wind energy is considered as one of the most prospective, developed and ecologically clean power source.

Summary potential of airflows is approximately 50 times larger than total energy necessities of humanity. As to Ukraine, nowadays theoretical sources of wind (or total kinetic energy of airflows) within its territory exceed almost 150 times above electrical power production [1]. Nevertheless, wind sources of the mainland, which can be practically consumed at present stage of wind technique development, exceed almost twice above the amount of power consumption of Ukrainians. Furthermore, except wind energy on the territory of Ukraine it is possible to use highly efficient energy of solar radiation, develop hydropower and bioenergetics stations etc.

As regards the negative influences of wind-power energetics on the environment, noise factors are the most dangerous. The noise level directly near the wind turbine may vary from 32 to 56 dB, and the level of infrasonic pressure – from 96 to 106 dB [1]. Comparing these values with the noise of refrigerator – 40 dB, passenger car – 55 dB, sweeper – 80 dB, blender – 90 dB, we may ascertain the fact that wind turbines are not more dangerous than most of domestic appliances or transport vehicles [1]. All the more, the noise emission during the wind turbine operation doesn't go beyond several hundreds of meters from the basing place.

Thus, it may be stated that our country can completely provide itself with energy due to the use of alternative ecologically clean power sources (wind, sun, rivers and biological sources). And what is more, we might sell the excess of electrical energy and use the gained asserts for further development of alternative power energetics and electric transport and for application of energy-efficient technologies in industry and agriculture. In addition to this, the considered ways of development of Ukrainian fuel and energy complex might allow improving of ecological situation in our country, so far as several wind turbines with total power of 1 MW allow reducing of yearly atmospheric emission of 1800 tons of carbonic acid gas, 9 tons of Sulphur oxide, 4 tons of nitric oxide.

II. Mechanisms of power regulation, rotation frequency stabilization and anti-storm protection of horizontal-axis wind turbines

Wind speed time fickleness is one of unfavorable wind energy features. Wind speed can change few times more during several seconds. This situation negatively effects on characteristics of power, generated by wind turbine, and on strength parameters of its various parts (for example, blades) [2]. Most wind turbines are equipped with special regulation systems for ensuring effective and reliable functioning in conditions of changeable wind speed and load on drive shaft. These regulation systems mainly operate at the expense of blades turning and folding or wind-wheel deflection out of wind direction. Usually electric and hydraulic drives are used in regulation systems of wind turbines of middle and large power (more than 100 kW). Small wind turbines are equipped with mechanical regulation systems for the purpose of cost reduction of their constructions [2].

It is reasonable to equip low-speed multiblade wind turbines with systems of power regulation by means of wind turbine blow-off area control [2]. Multiblade wind turbines have large filling factor of blow-off area. This factor allows effective using of air flow ram pressure on blades surfaces as a driving force for blades folding mechanisms of systems of rotor getting out of wind direction. From the point of view of efficiency and accuracy of regulation it is reasonable to equip high-speed wind turbines (less than 6 blades) with mechanisms of blades turning [2]. However, from the point of view of structure cost reduction it is reasonable to equip high-speed wind turbines with mechanisms of rotor blow-off area control.

Thus, creation of combined mechanical systems, which unite mechanisms of blades turning and folding, blades turning (or folding) and rotor getting out of wind direction is one of priority tasks of further development of horizontal-axis wind turbines constructions. It is planned, that these combined systems will offers all advantages of each regulation method in the future.

Let's consider simplified kinematic diagrams of mechanisms of blades turning and folding of horizontal-axis wind turbine (fig. 1, a, b) [2; 3; 4]. Blades are pivotally connected with rotor hub, which is rotating

round horizontal axis. Blades turning into feather position is realized as a result of regulating slider H_1 movement along wind-wheel axis and changing of hinges C and K positions (fig. 1, a). The process of blades folding is realized by means of regulating slider H_2 movement along wind-wheel axis (fig. 1, b). This slider changes blades angular position relative to wind-wheel axis (rotor tapering or conicity) and wind turbine blow-off area by changing positions of hinges N and E . The force of ram pressure is driving force for blades turning and folding in case of passive regulation. When using inertial regulator, the centrifugal force of regulation weights can be used by way of driving force also [2; 3; 4].

Combined mechanical system of blades turning and folding (fig. 1, c) may be received by combining of the mechanism of blades folding (fig. 1, b) with the mechanism of blades turning round their own longitudinal axis (fig. 1, a). The presence of hinges B and D , which are placed on rotor hub when using combined mechanism, allows blades turning round two mutually perpendicular axes. Mentioned movements can be independent, when sliders H_1 and H_2 are not joined or are connected by spring elements. Also these movements can be dependent, when sliders H_1 and H_2 are immovably joined [2; 3; 4].

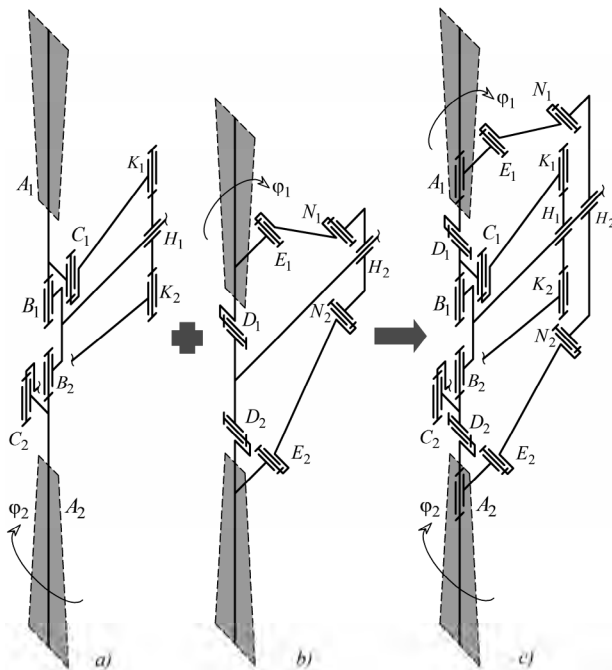


Fig. 1. Kinematic diagrams of the mechanism of blades turning (a), of the mechanism of blades folding (b) and of the combined mechanical system of blades simultaneous turning and folding (c)

When combining the blades turning (folding) system with the mechanism of wind-wheel getting out of wind direction tail-plane joins with nacelle by way of cylindrical hinge and interacts with nacelle through spring element [2]. Wind-wheel can be equipped with side blade, which is used for wind-wheel sideways turning relative to wind direction when wind speed rising over its nominal value. Similar effect can be achieved as a result of wind-wheel axis side-shift relative to tower axis or, in other

words, when existing of eccentricity between wind-wheel and tower axes [2].

Conclusions

Each regulation method has its own advantages, faults and usage scopes (high-speed wind turbines with 2-3 blades or low-speed multiblade wind turbines). When analyzing transient modes of wind turbine operation (especially coherent or storm wind gusts), existent mechanical systems of power regulation are not sufficiently effective taking into consideration large detention lag of their actuation and problems of equipping by effective feedback systems. These problems appear when power regulating according to changing of wind speed or load moment on driving shaft. These problems mainly concern to the systems of wind-wheel getting out of wind direction and cause necessity of usage of extra (friction or electromagnetic) wind-wheel braking systems (blades turning or folding systems etc.). That's why, the expediency of combined usage of blades turning (folding) systems and systems wind-wheel getting out of wind direction is substantiated in the article. It is planned, that these combined regulation systems ensure effective and reliable wind turbines operating under conditions of coherent and storm wind gusts. At that, simplified kinematic scheme of the mechanism of blades simultaneous turning and folding is proposed and general principles of its functioning are analyzed.

Further investigations provide for creating of mathematical models of wind turbine aeromechanical system with proposed regulation mechanisms, derivation of analytical dependencies for determination of their inertial and rigidity parameters, realization of computer modelling of wind turbine operating in transient modes and substantiation of expediency of usage of proposed regulation mechanisms.

References

- [1] Kuzio I. V., Korendiy V. M. "Obgruntuvannia rozvytku vitroenerhetychnykh ustanovok maloi ta nadmaloi potuzhnosti" ["Substantiation of Development of Wind Turbines of Low and Sublow Power"]. *Visnyk Natsionalnoho universytetu «Lvivska politekhnikha»*, 2010, № 679, pp. 61-68.
- [2] Korendiy V.M., Kuzio I.V., Vergeles V.V. "Analysis of power regulation mechanisms of horizontal-axis wind turbines and prospects of their improvement". *Visnyk Natsionalnoho universytetu «Lvivska politekhnikha»*, 2014, № 788, pp. 92-100.
- [3] Korendiy V. M. "Combined mechanical systems of power regulation of horizontal-axis wind turbines". *Environment protection. Energy saving. Sustainable environmental management: proceedings of the third International congress held from 17-19 September 2014 in Lviv*, pp. 68.
- [4] Korendiy V. M., Lozynskyy V. I. "Kinematic analysis of combined mechanical systems of simultaneous blades turning and folding of horizontal-axis wind turbines". *Avtomatyzatsiia vyrobnychkykh protsesiv u mashynobuduvanni ta pryladobuduvanni: Ukrainskyi mizhvidomchyi nauko-tekhnichnyi zbirnyk*, 2014, № 48, pp. 38-46.