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Adaptive transmission of wind turbine

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Abstract: Adaptive transmission represents a wheelwork which is converting a variable rotational velocity of a wind wheel to constant rotational velocity of the generator shaft. Advantages of adaptive transmission: simplicity and reliability. The principle of act of adaptive transmission is based on use of the "Effect of force adaptation" in the kinematic chain with two degrees of freedom (at the science discovery). The research problem: to develop the scheme of the adaptive mechanism and regularity of interacting of its parameters for creation of highly effective wind turbines.

Keywords: Adaptive Transmission, Force Adaptation, Gear Differential

1. Introduction

Transmission for transfer of motion from a wind turbine wheel to the generator shaft is a subject of inquiry.

Following designs are used for this purpose:

- Controlled change of a position of blades of the wind wheel and use of means of electronics for correction of frequency of the produced electric power [1]. Wind power set has next applications: complex mechanism of blades, the multistage reductor between the wind wheel and the electric generator, an electronic control system of frequency, an electronic control system of a position of blades. These solutions are complex, have low efficiency of the windmill and reliability of its work, and also increase its cost.
- Use of hydrodynamic transfers from a wind wheel to the generator, allowing to convert a variable rotational velocity of the wind wheel to constant rotational velocity of the generator shaft [2, 3]. Hydrodynamic transfer contains the gear step-up gear, the gear differential mechanism with two degree of freedom and the locking device in the form of the hydrodynamic converter which connects links of the differential mechanism to possibility of their relative motion. Such transfer has extremely difficult design which contains hydrodynamic transfer, a multistage wheelwork, the gear shift mechanism and a control system of transfers. Hydrodynamic transfer has unsatisfactory quality of the control system admitting failures and lapses, complexity of maintenance service and repair.
- Frictional stepless adjustable transfers in the form of frictional variators, including metal stepless-controlled belting of Miltenovich [1], also possess low reliability at high constructive complexity.
- Harris's transfer [4]. This transfer is executed without the hydraulic converter; however for start-up it uses a retardation of one of wheels that demands management.

Scientific novelty of the design consists in use of the discovery of Ivanov K.S. published in world press «Effect of force adaptation in mechanics» [5, 6, 7] with the solution of an inverse problem of force adaptation (to convert variable rotational velocity of the wind wheel to constant rotational velocity of the generator shaft). The discovery allows to create the adaptive drive of the generator as a stepless wheelwork with the service electric motor setting the demanded rotational velocity of the generator shaft . The adaptive mechanism has the constant cogging of toothed wheels. It works without hydrodynamic transfer, the gear shift mechanism and a control system. The offered mechanical adaptive gearing performs work only at the expense of mechanical properties on the basis of effect of force adaptation. This transfer is simple in design, reliable and absolutely adequate to working conditions.

Gear adaptive transfer is developed and patented in Germany [8], Kazakhstan [9, 10 and 11] and Russia [12]. Testing of the adaptive gearing has been executed in Italy [16].

Regularity of power adaptation has allowed to develop and to patent the adaptive drive of the wind turbine generator [13, 14 and 15]. However this drive uses only a part of energy of the wind stream, matching to the power of an engine which rotates the generator shaft with constant frequency.

The research problem: to develop the scheme of the adaptive drive of the generator and regularity of interacting of its parameters for creation of the elementary highly effective wind turbines completely using a wind power.

Work is based on mechanics laws.

2. Scheme of Adaptive Transmission

The scheme of adaptive transmission of the wind turbine is presented on fig. 1. The generator drive contains wind wheels 1 and 2, rotated in opposite sides, a differential wheelwork with two degree of freedom, containing wheels 3, 4, 5, 6, 7 and the carrier 8, the auxiliary electric motor of an alternating current with the mobile stator 9, the basic three-phase alternating-current generator 10 and the electric constant-current generator 11 for exciting coils of the basic generator 10.

In an operating time the variable speed wind sets in wind wheels 1 and 2 which are rotated in opposite sides. Wind wheels 1 and 2 transfer motion to the adaptive mechanism 3-4-5-6-7-8 with two degree of freedom. The adaptive mechanism by means of the carrier 8 sets in the stator of the auxiliary electric motor of the alternating current 9 which rotor rotates a rotor of the basic generator 10.

The auxiliary three-phase electric motor 9 gains a part of energy from the three-phase generator 10 (in volume about 10 % of power of the basic generator) and carries out step-up gear function, increasing speed of rotate of the carrier 8. The auxiliary three-phase electric motor 9 provides a constant rotational speed of a rotor of the basic generator 10 at a variable speed of a wind stream.

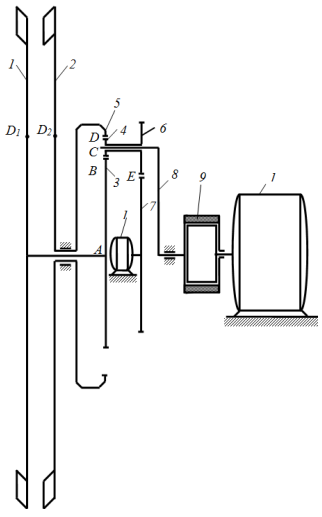

Fig 1. *The adaptive drive of the generator0.*

Simultaneously the toothed wheel 7 drives sets in the generator 11 direct currents which feeds exciting coils of the basic generator 10.

Speed of rotate of a rotor of the generator 7 and a strength of current depends on speed of a wind stream. Therefore power of the basic generator 10 will depend on power of a wind stream.

Thus, the basic alternating-current generator 10 will produce an electric current with constant frequency, but with the variable power depending on power of a wind stream.

3. The Basic Theoretical Regularity

The adaptive mechanism distributes speeds of motion of links according to a picture of speeds (Fig. 1). Linear speeds of points are presented by horizontal lines. Angular speeds of links are presented by inclined lines.

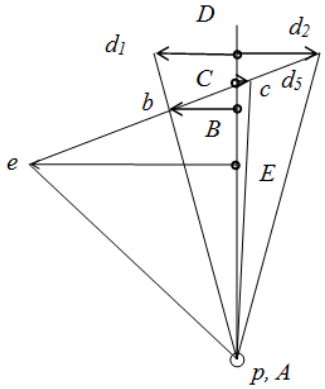

Fig 2. *A picture of speeds of the adaptive mechanism*

In a picture of speeds on vertical line pD points of the beginning of vectors of speeds are placed. The ends of vectors of speeds are marked out by matching small letters.

Speeds of wind wheels 1 and 2 are directed to opposite sides. In a picture of speeds linear speed of point D_1 of a wheel 1 is presented by piece Dd_1. Linear speed of point D_2 of a wheel 2 is presented by piece Dd_2. Lengths of pieces are equal $Dd_1 = Dd_2$. Speeds of points D of a wheel 5 and wheels 4 are equal and equal to speed of point D of a wheel 2 (are defined by pieces $Dd_5 = Dd_4 = Dd_2$). Inclined lines pd_1 and pd_2 define lines of angular speeds of links 1-3 and 2-5. Piece Bb defines linear speed of point B of wheels 3 and 4. Having connected points d_5 and b, we will gain line d_5bc of angular speed of the satellite 4-6. Point c on this line restricts piece Cc defining linear speed of point C of a link 4-6 and carrier 8. Line pc defines angular speed drove 8. On continuation of line d_5b of angular speed of the satellite 4-6 point e defining piece Ee of linear speed of point E of links 6 and 7 lays. Inclined line pe defines angular speed of a link 7. From a picture of speeds it is visible, that owing to symmetry of figure pd_1d_2 characterizing rotate of wheels 1 and 2 in opposite sides, angular speed of rotate of the carrier 8 (line pc) is very small in comparison with angular speeds of rotate of wind wheels 1 and 2 ($\omega_8 \approx \frac{1}{6}\omega_2$). Change of angular speed of wind wheels matches to change of power of a wind stream. We will mark out k - factor of change of power of a wind stream

$$k = N_{\max} / N_{cp}$$

Where $N_{\max}, N_{cp}$ - maximum and average powers of a wind stream on which angular speed ω_8 of carrier 8 depends.

Angular speed of a rotor of the generator

$$\omega_{10} = \omega_8 + \omega_9$$

Where $\omega_9 = const$ - angular speed of the auxiliary electric motor 9. In the description any numerical values of parameters in the capacity of an instance are resulted: $\omega_9 = const = 150$ radian/s.

Change of angular speed of a rotor of the generator 10 is equal to change of angular speed of the target carrier 8, that is $\Delta\omega_{10} = \Delta\omega_8$, as $\omega_9 = const$. Angular speed drove 8 according to a picture of speeds in n time ($n \approx 6$) less than angular speed of wind wheel $\omega_8 = \omega_2 / n$ (for example, at $\omega_2 = 6$ rad/s, $\omega_8 = 1$ rad/s). Hence $\Delta\omega_{10} = \Delta\omega_8 = \Delta\omega_2 / n$ (that is, in the capacity of instance $\Delta\omega_2 = 1$ rad/s).

Change of angular speed of wind wheel $\Delta\omega_2$ depends on change of power of wind stream ΔN.

At linear dependence between power of a wind stream and angular speed of a wind wheel

$\Delta N = k\Delta\omega_2$,

Where $\Delta N = N_{\max} - N_m$.

Here $N_{\max} = k\omega_{2\max}$, $N_m = k\omega_2$.

Then $\Delta\omega_2 = (N_{\max} - N_m)/k$.

$\Delta N = k(\omega_{2\max} - \omega_2)$. From here $\Delta\omega_2 = \omega_{2\max} - \omega_2$.

At factor of change of power of wind stream k =2 we will gain

$N_{\max} = kN_m = 2N_m$ And $\Delta N = N_m$.

Then $\Delta\omega_2 = N_m / k = \omega_2$

And $\omega_{2\max} = \omega_2 + \Delta\omega_2 = 2\omega_2 = 12$ radian/s, $\omega_{2\min} = \omega_2 - \Delta\omega_2 = 0$.

Let's define coefficient of motion irregularity of a generator rotor δ on which quality of the electric power produced by the generator depends

$\delta = (\omega_{\max} - \omega_{\min})/\omega_m$.

Here $\omega_{\max} = \omega_{8\max} + \omega_9 = \frac{\omega_{2\max}}{n} + \omega_9$,

$\omega_{\min} = \frac{\omega_{2\min}}{n} + \omega_9$,

$\omega_m = (\omega_{\max} + \omega_{\min})/2$ - Average angular speed of a rotor of the generator 10.

In the capacity of an instance at k =2, $n = 6$, $\omega_2 = 6$ rad/s we will gain.

$\omega_{\max} = 152$ rad/s, $\omega_{\min} = 150$ rad/s, $\omega_m = 151$ rad/s, $\delta = 0.03$, that is admissible for individual installations (standard coefficient of irregularity for electric generators $\delta = 0.02$). 10 it is possible to consider angular speed of a rotor of the basic generator approximately as a constant. It provides reception of a variable electric current of the generator of constant standard frequency. Such parameter of the generator matches to the standard on consuming electric power techniques.

Further, the toothed wheel 7 drives the direct current generator 11 which feeds exciting coils of the basic generator 10. Apparently from a picture of speeds, angular speed of a wheel 7 (inclined line pe) and a rotor of the generator 11 much more angular speed of wind wheels 1 and 2, that provides reception of an electric current for exciting coils of the generator 10 with demanded parameters. Speed of rotate of a rotor of the generator 7 and strength of current depends on speed of a wind stream. Therefore power of the basic generator 10 will depend on power of a wind stream.

Thus, the drive of the basic alternating-current generator will provide full use of energy of a variable wind stream. The basic generator will produce an electric current with constant frequency, but with the variable power depending on power of a wind stream.

Achievement of standard parameter of the produced electric power is attained without use of any control system that provides the maximum simplicity of a design and reliability of work of the wind-driven electric plant.

The kinematic and force analysis of the mechanism is carried out according to regularity of interconnection of parameters of the kinematic chain with two degrees of freedom [5, 13 and 14].

The given parameters for a wind stream of average power are: speeds of rotate of wind wheels 1 and 2, the driving moments on wind wheels 1 and 2, speed of rotate of the shaft of the basic generator.

The subjects to definition are: power of an electric current produced by the generator, rotational velocities of all links, moments of resistance on links, power of the exciting coil generator.

4. Conclusion

The developed scheme of the wind turbine procures transformation of variable wind energy to electric energy of the asynchronous generator with constant frequency of an electric current. Presence of two wind wheels rotated in opposite sides, provides an effective utilization of wind energy, an equilibration of wheels and adaptation to a direction of a wind stream. The developed scheme creates basic new way of use of wind energy. The scheme has two degrees of freedom that allows dividing variable wind energy into two directions: the drive of the shaft of the basic three-phase generator and the drive of the auxiliary generator for a field winding current.

The divided energy streams are uniting on the basic generator again. The closed contour of an energy transfer is occurring. Such event procures a new free-running effect as a result: the full using of wind energy and receipt of electric current of constant frequency without a control system.

The developed theoretical regularity of interconnection of parameters of adaptive transmission of the wind turbine is based on use of discovery «Effect of power adaptation in the mechanic». This regularity allows determining technological parameters of adaptive transmission and to execute kinematic and force calculation of the wind turbine for working out of a concrete design. Adaptive transmission of the wind turbine effectively uses a wind power, is independently accommodated for variable wind energy without use of a control system and has constructive simplicity.

Adaptive transmission of the wind turbine defines prospects of development of wind-power engineering.

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