Title: HIGH-EFFICIENCY OSCILLATING-BLADE WIND TURBINE

Abstract: The wind turbine has a central axis that supports pairs of blades offset by 90°, each pair is integral with a single supporting shaft able to rotate relative to the central axis of the turbine owing to coupling by means of bearings. The pairs of blades are orientated automatically in order to present the maximum possible surface area of the blades to the wind when they move in the direction of the wind, at the same time minimizing the surface area of the blades when they move against the wind. The large surface exposed to the action of the wind is not opposed by a braking action due to the blades moving against the wind, which produces a very high torque on the central axis. The turbine operates with the wind blowing from any direction and is able to start moving even in the presence of very light winds.

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HIGH-EFFICIENCY OSCILLATING-BLADE WIND TURBINE

Field of the invention
The present invention relates to a wind turbine rotating about a vertical axis for transforming wind energy to mechanical energy. Its main use is as a generator of electrical energy, and in that case the connected device effects a conversion of energy, but other uses are possible, for example operating a hydraulic pump.

Prior art
The ever increasing global interest in alternative energy sources, including wind energy, which proves far more competitive than photovoltaic in terms of cost per kW, has spurred on research into new solutions for developing wind turbines with better and better performance. The majority of wind power installations envisage the use of horizontal-axis turbines, which, in order to have high efficiency, need large blades and lend themselves poorly for use in a market with the greatest potential such as that represented by mini- or micro-generation of energy for use by individual houses, blocks of flats, or small companies. Moreover, horizontal-axis wind turbines are excessively noisy and aesthetically unwieldy. Compact turbines with vertical axis of rotation and with fixed blades, which generate little noise on account of the reduced speed of rotation, are also already known. However, solutions of this kind still have relatively low efficiencies. There have in fact been attempts to improve the efficiency of the turbines by using vertical-axis wind turbines with blades having movable or variable profile.

For example, one solution is proposed in document CN2471963Y. This patent describes a wind turbine with vertical axis of rotation that uses blades which, in the phase of motion against the wind, can rotate about a horizontal axis thereof and have a cut-off for maximum reduction of aerodynamic resistance. This solution requires extremely light blades otherwise not even a wind of medium intensity is able to lift them so that they are arranged flat. Consequently a turbine of this kind requires wind having a rather high minimum velocity for the start of operation and a design that is not very robust, as it is difficult to reconcile lightness and robustness, unless very expensive materials are used. Moreover, in the phase of motion against the wind the blades will be subject to numerous oscillations about the horizontal equilibrium configuration, which might cause greater aerodynamic
resistance than that generated by blades with perfectly horizontal disposition. Moreover, forces may be generated that disturb the equilibrium of the vertical axis, increasing the friction in the bearings supporting it and allowing rotation relative to the supporting tower.

Patent CN101539100A discloses a turbine with vertical axis of rotation thereof and with each blade having an axis of oscillation thereof that is vertical, and parallel to the main rotation axis of the turbine. In this case too, for proper operation of the turbine the blades must be very light and so are not very robust. The oscillations of the blades about their own axis during the main rotation of the turbine are greater than in the preceding solution, since in this second solution an equilibrium is established, that is continually changing, between forces of inertia, centrifugal forces, and the action of the wind, which acts on the blades with variable angles in the various positions that they assume during rotation. As in the preceding case, the oscillations of the blades about the constantly changing equilibrium configuration might cause greater aerodynamic resistance than expected, and generate forces that disturb the equilibrium of the central vertical axis of rotation of the turbine, increasing the friction in the bearings that support it.

To summarize, these patents attempt to solve, in different ways, the problem of maximizing efficiency by reducing the resisting torque produced by the blades moving against the wind. However, there is a need for a further increase in wind turbine efficiency, eliminating the disadvantages of the known solutions.

Summary of the invention

The purpose of the present invention is to provide a wind turbine for transforming wind energy to mechanical and electrical energy with vertical axis of rotation and whose efficiency is better than that of the known turbines.

The present invention relates to a wind turbine having the features of claim 1. Owing to its new design concept, the wind turbine of the invention tackles the problem of maximizing the efficiency of vertical-axis wind turbines by substantially reducing the aerodynamic resistances that are created during operation. The turbine is able to operate with wind coming from any direction and is able to rotate even in the presence of very light winds. The design of the turbine is economical, robust, compact and safe. It is a design of the modular type, because starting from
a basic design that uses a minimum number of blades necessary for its operation, it is possible to add other blades for scaling the power that can be supplied, based on user requirements.

The dependent claims describe preferred embodiments of the invention, forming an integral part of the present description.

**Brief description of the drawings**

Further characteristics and advantages of the invention will become clearer on reading the detailed description of preferred, but not exclusive, embodiments of a vertical-axis wind turbine, illustrated as a non-limiting example, with the aid of the appended drawings in which:

Fig. 1 shows an axonometric view of the turbine according to the present invention;

Fig. 2a shows a side view of the turbine of Fig. 1 in an operating position;

Fig. 2b shows a top view of the turbine of Fig. 1 in the operating position corresponding to that of Fig. 2a;

Fig. 3a shows a side view of the turbine of Fig. 2 in a second operating position;

Fig. 3b shows a top view of the turbine of Fig. 2 in the operating position corresponding to that of Fig. 3a;

Fig. 4a shows a side view of the turbine of Fig. 2 in a third operating position;

Fig. 4b shows a top view of the turbine of Fig. 2 in the operating position corresponding to that of Fig. 4a;

Fig. 5a shows a side view of the turbine of Fig. 2 in a fourth operating position;

Fig. 5b shows a top view of the turbine of Fig. 2 in the operating position corresponding to that of Fig. 5a;

Fig. 6a shows a side view of the turbine of Fig. 2 in a fifth operating position;

Fig. 6b shows a top view of the turbine of Fig. 2 in the operating position corresponding to that of Fig. 5a;

Fig. 7a shows a side view of the turbine of Fig. 2 in a sixth operating position;

Fig. 7b shows a top view of the turbine of Fig. 2 in the operating position corresponding to that of Fig. 7a;

Fig. 8a shows a side view of the turbine of Fig. 2 in a seventh operating position;
Fig. 8b shows a top view of the turbine of Fig. 2 in the operating position corresponding to that of Fig. 8a;

Fig. 9a shows a side view of the turbine of Fig. 2 in an operating position like that of Fig. 2a with the wind direction reversed;

Fig. 9b shows a top view of the turbine of Fig. 2 in the operating position corresponding to that of Fig. 9a;

Fig. 10a shows a side view of the turbine of Fig. 2 in a configuration determined by the action of the wind starting from the situation of Fig. 9a;

Fig. 10b shows a top view of the turbine of Fig. 2 in the operating position corresponding to that of Fig. 10a.

The same reference numbers and same reference letters in the figures identify the same elements or components.

**Detailed description of preferred embodiments of the invention**

Referring to Fig. 1, the wind turbine globally indicated with the number 1 comprises a central supporting member 2, made for example in the form of a tube of metallic material or of glass-fibre reinforced plastic of suitable diameter to ensure rigidity of the turbine 1. At a predetermined height, two blades 3 and 4 are fixed on the member 2, the first blade 3 arranged in a position diametrically opposite to the second blade 4 relative to the axis Z of the member 2 which is also the vertical axis of rotation of the turbine 1, forming a pair of blades. In Fig. 1, blade 3 is shown in the extended or opened position, while blade 4 is shown in the closed or retracted position. Blade 3 consists of two half-blades 5 and 6 each fixed to a respective rod 7 and 8. Rod 7 is able to rotate about the horizontal axis of rotation X1 in the direction indicated by arrow C1 in the closing direction, and rod 8 is able to rotate about the horizontal axis of rotation X2 in the direction indicated by arrow C2 in the closing direction.

The shape of blade 4 is completely identical to blade 3 and the two rods 7 and 8, which extend beyond axis Z symmetrically, also constitute the support of the two half-blades 9 and 10, constituting blade 4, which are fixed to them. In this way the half-blade 5 is fixed to the same rod 7 to which half-blade 9 is fixed, but offset by 90°, relative to axis X1, while half-blade 6 is fixed to the same rod 8 to which half-blade 10 is fixed, but offset by 90°, relative to axis X2. The two upper half-blades 5
and 9 therefore have the horizontal axis of rotation X1 in common and the two lower half-blades 6 and 10 have the horizontal axis of rotation X2 in common. Each of the two rods 7, 8 can be made as a single piece or as two half-rods joined together integrally. Therefore the same rotation of rods 7 and 8 about the axis thereof, in a respective predetermined direction that causes the half-blades 9 and 10 of blade 4 to assume the closed position thereof, causes half-blades 5 and 6 to assume the opened position thereof. In this first embodiment, the two rods 7 and 8 are free to rotate independently about the axis thereof from one another.

As an alternative, a further embodiment according to the invention envisages that the wind turbine is constructed with the two rods 7 and 8 connected together so that rotation of a first rod, e.g. rod 7, clockwise through a given angle, corresponds to an equal rotation of the second rod, e.g. rod 8, anticlockwise through the same angle and, conversely, a rotation of the first rod 7 anticlockwise through a given angle corresponds to an equal rotation of the second rod 8 clockwise through the same angle. In the case of this design variant in which there is a rotatable connection between the two rods 7 and 8, coupling can be provided advantageously, but not exclusively, by means of toothed gears or by means of a crossed belt, or by an equivalent kinematic system.

For example, in Fig. 1 the half-blades 9 and 10 rotate according to the arrows C1 and C2, passing from the closed position, shown, to the next opened position, not shown. The position of the blades 3, opened, and 4, closed, corresponds to a direction of the wind blowing in the direction indicated by arrow V.

Fig. 1 also shows the presence of a second pair of blades 13 and 14 offset by 90° relative to the upper pair of blades 3 and 4 and structurally entirely similar to the first blades. Blade 13 consists of two half-blades 90 and 100 each fixed respectively to rods 70 and 80, parallel to one another, oscillating about the respective axes X3 and X4. Blade 14 consists of two half-blades 50 and 60, fixed respectively to the two rods 70 and 80 in a position with angular offset of 90° relative to half-blades 90 and 100.

Fig. 1 shows an embodiment of the invention that envisages a turbine with two pairs of blades, offset angularly and offset by height; however turbine 1 is of modular design, and, starting from the design illustrated that uses the minimum
number of blades necessary for its operation, other blades are added for scaling the power that can be supplied based on user requirements.

Each of the two pairs of blades 3 and 4, 13 and 14 is integral with a single supporting member 2 that is able to rotate relative to the central axis Z of the turbine owing to a coupling by means of rolling bearings. The supporting member 2, which is advantageously, but not exclusively, a metal tube of circular section, is supported by a base 15 by fixing means, provided with rolling bearings or equivalent, which allows its rotation about axis Z and is suitably connected mechanically to a device, not shown, that makes it possible to utilize the power supplied by the turbine. The base 15 is in its turn fixed to a structural member fixed to the ground or to the structure of a building or to any other equivalent supporting structure.

The turbine 1 mainly finds application as a generator of electrical energy, and in that case the connected device will effect conversion of energy, but it is suitable for other uses, for example operation of a hydraulic pump or of some other mechanical device of a known type that requires a motor for its operation.

Owing to the manner in which the blades of each pair are connected together, the blades are orientated automatically in the opened position in order to present the maximum surface area to the wind when they move in the direction of the wind and are arranged in the closed position when they move in the direction opposite to the wind, at the same time minimizing the surface area of the blades.

With particular reference to the sequence from Fig. 2 to Fig. 8, the operating principle of the turbine is shown in detail. Let us assume for convenience of the account that the initial configuration of the turbine is that of Fig. 2, which shows a front view of the turbine in an operating position at the start of rotation. The wind direction is that entering orthogonally to the sheet of paper, as is clear from the top view of the turbine (Fig. 2b) where the wind direction is indicated by arrows 20, while the direction of rotation is indicated by arrow 21.

It should be noted, however, that the turbine is able to start moving whatever the wind direction, as illustrated later in the description.

The two half-blades 5 and 6 constituting blade 3, which are located to the left of the central axis Z, relative to the drawing, are open and expose their maximum
surface area to the wind pressure, while the two half-blades 8 and 9 of blade 4 that
are located to the right of axis Z of turbine 1 are cut in the closed position and are
not subjected to any marked action by the wind. Only the two half-blades of the
upper pair, that are located on the left, react to the wind, instead the two lower
blades 13 and 14 are perpendicular to the action of the wind, which does not exert
any marked aerodynamic force, since their supporting rods are aligned with the
wind direction. It is important to emphasize that the half-blades 5 and 6 of blade 3
on the left in Fig. 2 in the opened position, although being integral with rods 7 and
8 able to rotate relative to the central axis Z, cannot move since the rotation that
the wind would impart to them is opposed by the other two half-blades 9 and 10 of
the upper blade 4, located on the right, which are already in contact along the
edges and therefore prevent rotation of rods 7 and 8 in the required direction of
the half-blades on the left.
Owing to the aerodynamic pressure exerted on the opened blade 3, there will
therefore be a substantial torque about axis Z which, even in the presence of light
winds, will cause rotation of the turbine clockwise relative to an observer viewing
from above, see Fig. 2b.
The turbine, which now begins to rotate under the action of the wind, assumes the
configuration shown in Fig. 3a rotated by an angle of less than 90° relative to the
initial configuration. The two arrows indicate the half-blades of the lower blade that
are acted upon by a strong wind pressure in this new position, since the half-
blades move against the wind, and as they are free to rotate, they will start to
move, as shown in the next figures, which will lead them to assume the closing
configuration. This time the half-blades on the opposite side, i.e. those constituting
the lower blade on the left, will not block the rotation of the fastening rod since the
moment generated by the blades on the right about the two fastening rods will
tend to make them rotate in order to move them away. Meanwhile, the half-blades
of the upper blade on the left still expose fairly extensive surface areas to the
action of the wind, maintaining the turbine rotation.
In Fig. 4a, the turbine is shown in a configuration rotated through an angle a little
larger than that in Fig. 3a and 3b and the lower blades are rotating to assume a
new equilibrium configuration as a result of the actions described for the
configuration in Fig. 3a and 3b. As soon as the moment generated by the half-blades of the lower blade on the right is such as to cause the fastening rod to rotate, the half-blades of the lower blade on the left are led to expose an ever larger surface area to the wind. The aerodynamic pressure of the wind on the half-blades of the lower blade on the left generates a moment that tends to cause the two fastening rods to rotate in the very same direction in which the half-blades of the lower blade on the right are moving. The two moments are added together, causing a rapid rotation of the fastening rods of the half-blades about their axes of rotation X3 and X4 which will lead the lower blade on the left to expose the maximum surface to the action of the wind, arriving at the configuration in Fig. 5a, rotated through an angle a little larger than that of the preceding figure. In this configuration the half-blades of the pair of lower blades have reached the new equilibrium configuration where one lower blade is opened and the other lower blade is closed.

It is not possible to predict exactly when the two lower blades will rotate through 90° about axes X3 and X4, since this depends on the force of the wind and on the frictional forces that oppose the rotation of the fastening rod of the half-blades; it can however be predicted that this occurs after a rotation of the turbine about axis Z through an angle between 30° and 60°, from the starting position in Fig. 2. From this point on, the torque required to keep the turbine rotating, and to operate the device for energy transformation connected to it, will be generated principally by the lower blade on the left and no longer by the upper blade on the left, which gradually exposes a smaller and smaller surface to the action of the wind, on account of the increasing inclination of the half-blades relative to the wind direction.

In the configuration shown in Fig. 6a, the turbine is arranged at an angle of 90° relative to the initial reference configuration. Comparing the configuration in Fig. 2 with that in Fig. 6a, it can be seen that after rotation through 90° about the vertical axis, turbine 1 has assumed a configuration similar to the initial configuration, except only that this time it is the lower half-blades that expose the maximum useful surface to the action of the wind, whereas initially it was the upper half-blades that were in the opened position. The sequence of movements described
by Figs. 2 to 6 will then be repeated with the parts inverted, with the blades of the lower pair performing the role that was performed by those of the upper pair, and vice versa.

Figs. 7a, 7b and 8a, 8b illustrate the configurations with successive passage of the turbine through the arc of 90°, during which the turbine returns to the initial configuration. The configuration in Fig. 7a shows turbine 1 rotated through an angle greater than 90° and less than 180° relative to the initial configuration. The configuration in Fig. 8a shows turbine 1 rotated through 180° relative to the initial configuration.

Let us illustrate the case when the wind begins to blow from a different direction relative to that described previously, for example the wind blows in the opposite direction, as shown in Fig. 9a, in which the wind direction is envisaged leaving orthogonally to the sheet of paper, as is clear from the top view in Fig. 9b where the wind direction is indicated by the black arrows.

The action of the wind on the upper blade on the right causes the half-blades to close, since in this case their rotation about their respective fastening rods is not prevented by the half-blades of the upper blade on the left, which instead undergo an opening movement, gradually exposing a larger and larger surface to the aerodynamic action of the wind that contributes to their opening movement in sympathy with the closing movement of the half-blades of the blade on the right. The upper blade on the right then assumes the position of maximum opening while the upper blade on the left assumes the closing position; consequently the turbine begins rotating clockwise due to the moment that the aerodynamic pressure on the open blade creates about the axis of rotation Z. This new equilibrium configuration is represented in Fig. 10.

It is to be considered that even in the case when the friction of the bearings about which the supporting rods of the half-blades rotate about axes X3 and X4 would be such as not to promote rotation of the half-blades, relative to the rotation of the central supporting member 2 about axis Z, something that is rather improbable since the central member 2 is also braked by the resisting torque that opposes the device for transformation or transmission of energy, the motion generated would lead the turbine to rotate at most through 180°, i.e. half a turn, as far as the
configuration in Fig. 10, and at this point the action of the wind would cause reversal of the direction of rotary motion of turbine 1 and everything functions as first described. Therefore in every case turbine 1 is able to start moving whatever the wind direction.

The elements and characteristics illustrated in the various preferred embodiments can be combined with one another while remaining within the scope of protection of the present application.
CLAIMS
1. A wind energy transformation turbine (1) comprising a longitudinal load-bearing member (2) defining a longitudinal axis (Z) thereof, adapted to be vertically arranged during the operation of the turbine (1), fastening means (15) for fastening the longitudinal member (2) to a supporting structure of the turbine (1) allowing the rotation of the longitudinal member (2) about the longitudinal axis (Z) thereof, at least one first pair of blades (3, 4) arranged in a first predetermined position along the longitudinal member (2) and at least one second pair of blades (13, 14) arranged in a second predetermined position along the longitudinal member (2) spaced from said first predetermined position along the longitudinal load-bearing member (2), wherein in the at least one first pair of blades (3, 4) a first blade (3) is arranged in a position diametrically opposite to a second blade (4) with respect to the longitudinal axis (Z), wherein in the at least one second pair of blades (13, 14), a first blade (13) is arranged in a position diametrically opposite to a second blade (14) with respect to the longitudinal axis (Z), and wherein the first and second blades (3, 4) of the at least one first pair of blades are angularly offset with respect to the first and second blades (13, 14) of the at least one second pair of blades by an angle of about 90° with respect to the longitudinal axis (Z), wherein said at least one first pair of blades (3, 4) comprises first and second fastening rods (7, 8) parallel to each other, wherein said at least one second pair of blades (13, 14) comprises first and second fastening rods (70, 80) parallel to each other, wherein each fastening rod defines a longitudinal axis (X1, X2, X3, X4) thereof and is radially fixed to the longitudinal member (2) so as to rotate over an arc of circle about said longitudinal axis (X1, X2, X3, X4) thereof, each of said blades (3, 4, 13, 14) comprising respective first and second half-blades (5, 6, 9, 10), wherein in said at least one first pair of blades (3, 4) and in said at least one second pair of blades (13, 14), respectively, the first fastening rod (7, 70) is integrally fixed with a first half-blade (5, 50) of the first blade (3, 13) and with a first half-blade (9, 90) of the second blade (4, 14) in an angular position offset by 90°
about the axis \((X_1, X_3)\) of the first fastening rod \((7, 70)\), and the second fastening rod \((8, 80)\) is integrally fixed with the second half-blade \((6, 60)\) of the first blade \((3, 13)\) and with the second half-blade \((10, 100)\) of the second blade \((4, 14)\) in an angular position offset by 90° about the axis \((X_2, X_4)\) of the second fastening rod \((8, 80)\),

wherein the first and second fastening rods \((7, 70, 8, 80)\) integrally oscillate with the two respective half-blades to which are fixed between a blade closing position, in which the surface on which the wind acts is the smallest, and a blade opening position in which the surface on which the wind acts is the greatest.

2. A turbine according to claim 1, wherein the half-blades have application surfaces of aerodynamic forces, generated by the wind, having flat shape.

3. A turbine according to claim 2, wherein the two half-blades of each blade in open position are arranged aligned with each other with the application surfaces lying on a common plane of the blade and, in closed position, the two half-blades are arranged with their application surfaces parallel to each other.

4. A turbine according to claim 3, wherein the respective first and second fastening rods \((7, 70, 8, 80)\) of each of said first and second pairs of blades are connected to each other so that an angular rotation of a first rod in a first direction corresponds to an angular rotation of the second rod in a direction opposite to the first direction by a same angular value.

5. A turbine according to claim 4, wherein a rotatable connection is provided between the two rods \((7, 8)\) and the coupling may advantageously be made by means of a toothed gear or by means of one or more crossed belts.

6. A turbine according to one of the preceding claims, wherein said pair of blades are two or more in number.

7. A turbine according to one of the preceding claims, wherein mechanical or electrical energy is obtained from said wind energy transformation.
Fig. 2
Blade on which a high pressure acts

Turbine rotation direction

Wind direction

Fig. 3
Fig. 4
Turbine rotation direction

Wind direction

(a)  (b)

Fig. 6
Fig. 8
Fig. 10
**INTERNATIONAL SEARCH REPORT**

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