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A STRUCTURALLY OPTIMIZED TILTED OR HORIZONTAL AXIS WIND TURBINE

BACKGROUND OF THE INVENTION

Despite decades of research and development, the cost of wind power remains higher than alternatives, such as fossil fuels. There is a large and unfulfilled need for a wind turbine with low cost per kilowatt. The current invention is directed to satisfying this need.

SUMMARY OF THE INVENTION

The invention is directed to a wind turbine.

The line of a rotor is defined as height of the lowest point of the circle, swept by the rotor.

The term 'guy wire' includes chains and linked rods, attached to support a tower similarly to guy wires.

An axial flow wind rotor is defined as a rotor which extracts energy from moving fluid mostly by changing the momentum of the fluid in the direction, parallel to the rotor's axis of rotation. In most cases, an axial flow rotor has one or more radial blades. A conventional horizontal axis wind turbine has an axial flow wind rotor, while vertical axis wind turbine has a radial (non-axial) flow wind rotor.

Various embodiments of the invention teach drastic improvements, fixing main inefficiency points of a conventional horizontal axis wind turbine: decrease or complete elimination of bending stress on the tower by combination of a tilted

axial flow wind rotor with guy wires support; decrease or complete elimination of bending stress on the blades by utilizing cable suspension or bracing; elimination of gearbox by utilizing mid-rotor or peripheral power take-off. Some of the embodiments are summarily described below in the following articles:

A1. A wind turbine, comprising:

a tower,

an axial flow wind rotor, installed on the tower;

a plurality of guy wires, supporting the tower;

where the guy wires are attached to the tower above the rotor line; and

the wind rotor's axis tilted in the vertical plane in such a way that the tower's centerline crosses said rotation plane above the tower.

A2. The wind turbine of Article A1, wherein the guy wires are attached near the top of the tower.

A3. The wind turbine of any of Articles A1 -A2, wherein the wind rotor is downwind from the tower.

A4. The wind turbine of Article A3, wherein the wind rotor is counterweighted.

A5. The wind turbine of any of Articles A1 -A2, wherein the wind rotor is above the tower.

A6. The wind turbine of any of Articles A1 -A5, further comprising an underground foundation for the wind turbine.

A7. The wind turbine of any of Articles A1 -A5, further comprising a buoy, allowing the wind turbine to float.

A8. The wind turbine of Article A7, wherein the wind turbine is floating in a sea or ocean and the guy wires are anchored at the bottom of the sea or ocean.

A9. The wind turbine of any of Articles A1 -A8, wherein the tower is of lattice type.

A10. The wind turbine of any of Articles A1 -A9, wherein the angle between the wind rotor's rotation plane and the vertical is between 5 and 45 degrees, inclusive.

A11. The wind turbine of any of Articles A1 -A9, wherein the wind rotor's axis is substantially horizontal.

A12. The wind turbine of any of Articles A1 -A11, wherein the angle between the wind rotor's rotation plane and the vertical is substantially equal to the angle between at least one of the guy wires and the horizontal plane.

A13. The wind turbine of any of Articles A1 -A12, wherein the rotor blades are supported by external cables in order to decrease their weight.

A14. The wind turbine of any of Articles A1 -A13, wherein the guy wires are designed to compensate at least most of the horizontal pressure, exerted by the wind on the wind rotor in operation.

B1. A method of converting wind energy into electrical energy, comprising:
providing a tower;

installing an axial flow wind rotor on top of the tower at an angle to the vertical;

supporting the tower with a plurality of guy wires, attached to the tower above the rotor line;

wherein the lower part of the wind rotor is turned away from the tower.

B2. The method of Article B1, wherein the guy wires are attached near the top of the tower.

B3. The method of any of Articles B1 -B2, wherein the wind rotor is placed downwind from the tower.

B4. The method of Article B3, wherein the wind rotor is counterweighted.

B5. The method of any of Articles B1 -B2, wherein the wind rotor is placed above the tower.

B6. The method of any of Articles B1 -B5, further comprising attaching the tower to an underground foundation.

B7. The method of any of Articles B1 -B5, further comprising attaching the tower to a buoy, allowing the wind turbine to float.

B8. The method of Article B7, wherein the wind turbine is floating in a sea or ocean and the guy wires are anchored at the bottom of the sea or ocean.

B9. The method of any of Articles B1 -B8, wherein the tower is of lattice type.

BI 0. The method of any of Articles BI -B9, wherein the angle between the wind rotor's rotation plane and the vertical is predefined and is between 15 and 45 degrees, inclusive.

BI 1. The method of any of Articles BI -B9, wherein the wind rotor is substantially horizontal.

BI 2. The method of any of Articles BI -BI 1, wherein the angle between the wind rotor's rotation plane and the vertical is kept substantially equal to the angle between at least one of the guy wires and the horizontal plane.

BI 3. The method of any of Articles BI -BI 2, wherein the rotor blades are supported by external cables in order to decrease their weight.

BI 4. The method of any of Articles BI -BI 3, wherein the guy wires compensate at least most of the horizontal pressure, exerted by the wind on the wind rotor in operation.

C1. A wind turbine comprising:

a wind rotor having a plurality of radial airfoil blades;

each blade being supported by at least one external cable; and

at least one drivetrain, coupled to the wind rotor, the drivetrain is adapted for power take-off from either mid-rotor or rotor periphery.

C2. The wind turbine of Article C1, wherein the power take-off is mid-rotor.

C3. The wind turbine of Articles C3, wherein each blade is attached to the rotor by a spar.

C4. The wind turbine of any of Articles C1-C3, further comprising a contact ring for power take-off, coaxial to the wind rotor.

C5. The wind turbine of Article C4, wherein the contact ring touches the blades or the spars.

C6. The wind turbine of Article C4, wherein at least some external cables are attached to the contact ring.

C7. The wind turbine of any of Article C4, wherein the contact ring is attached to the rotor.

C8. The wind turbine of any of Articles C1-C7, wherein the contact ring has teeth or recesses and the drivetrain comprises a gear, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator.

C9. The wind turbine of any of Articles C1-C7, wherein the drivetrain comprises a tire, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator; and the contact ring's surface has high friction coefficient with the tire.

C10. The wind turbine of any of Articles C1-C3, wherein the contact ring has teeth or recesses and the drivetrain comprises a gear, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator.

C11. The wind turbine of any of Articles C1-C3, further comprising a chain or a belt for power take-off, the chain or belt is coupled to at least two blades.

C12. The wind turbine of Article C3, further comprising a chain or a belt for power take-off, the chain or belt is coupled to at least two spars.

C13. The wind turbine of any of Articles C11-C12, wherein the drivetrain comprises a sprocket, engaging the chain or belt; and an electrical generator; the gear sprocket is rotationally coupled to the rotor of the electrical generator.

D1. A method of converting wind energy into electrical energy, comprising:

providing a tower with a wind rotor, having a plurality of radial airfoil blades;

supporting each blade against aerodynamic forces with at least one external cable;

performing mechanical power take-off from either mid-rotor or rotor periphery.

D2. The method of Article D1, wherein the power is taken-off mid-rotor.

D3. The method of Articles D3, wherein each blade is attached to the rotor by a light weight spar.

D4. The method of any of Articles D1-D3, wherein the power is taken off of a contact ring, coaxial to the wind rotor.

D5. The method of Article D4, wherein the contact ring touches the blades or the spars.

D6. The method of Article D4, wherein at least some external cables are attached to the contact ring.

D7. The method of any of Article D4, wherein the contact ring is attached to the rotor.

D8. The method of any of Articles D1 -D7, wherein the contact ring has teeth or recesses and the drivetrain comprises a gear, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator.

D9. The method of any of Articles D1 -D7, wherein the drivetrain comprises a tire, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator; and the contact ring's surface has high friction coefficient with the tire.

D1 0. The method of any of Articles D1 -D3, wherein the contact ring has teeth or recesses and the drivetrain comprises a gear, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator.

D1 1. The method of any of Articles D1 -D3, where in the power take-off is performed via a chain or a belt, the chain or belt being coupled to at least two blades.

D1 2. The method of Article D3, wherein the power take-off is performed via a chain or a belt, the chain or belt is coupled to at least two spars.

D1 3. The method of any of Articles D1 1-D1 2, wherein the drivetrain comprises a sprocket and an electrical generator, the sprocket being rotationally coupled to the rotor of the electrical generator; and the chain or belt engage the gear.

E1. A wind turbine, having a tower and an assembly, installable on top of the tower, the assembly comprising:

a base, capable of horizontal rotation on the tower;

an axial flow wind rotor, comprising:

a rotating hub;

a plurality of airfoil blades, coupled to the hub;

each blade is supported by at least one external cable;

a ring, external to the hub, coaxial to the wind rotor.

at least one drivetrain assembly, comprising:

an electrical generator with an electric rotor and a stator;

a rotational element, engaging the ring and rotationally coupled to the rotor of the electrical generator for power take off from the ring.

E2. The system of Article E1, where the tower is supported by three or more guy wires above the rotor line.

E3. The system of Article E2, where the tower is placed in a natural water body, while the guy wires are anchored at the bottom.

E4. The system of any of Articles E1 -E3, wherein the axis of the wind rotor is tilted in the vertical plane.

E5. The system of any of Articles E1 -E4, where the wind rotor is downwind from the tower.

E6. The system of any of Articles E1 -E5, where a counterweight is attached to the base.

E7. The system of any of Articles E1 -E6, where the rotational element is a gear.

E8. The system of any of Articles E1 -E6, where the rotational element is a tire.

E9. The system of any of Articles E1 -E8, comprising at least two drivetrains.

E10. The system of any of Articles E1 -E9, wherein the tower is of lattice type.

F11. A method of converting wind power into electrical power, comprising steps of:

harvesting wind power using an axial flow wind rotor, comprising:

a rotating hub, installed on top of a tower;

plurality of airfoil blades, coupled to the hub;

a ring, coaxial to the wind rotor, external to the hub, attached to the wings;

using at least one external cable to support each blade;

taking the harvested power off the ring and converting it to electrical power using an electrical generator.

F12. The method of Article F11, wherein the ring rotates horizontally, following changes in the direction of the wind.

F13. The method of any of Articles F11-F12, wherein the wind rotor is tilted upwind.

F14. The method of any of Articles F11-F13, wherein the tower is supported by three or more guy wires.

FI 5. The method of any of Articles FI 1-FI 4, wherein the tower is floating.

FI 6. The method of any of Articles FI 1-FI 5, wherein the rotor is counterweighted.

FI 7. The method of any of Articles FI 1-FI 6, wherein power take off is performed using a gear, and the ring is equipped with teeth for engaging the gear.

FI 8. The method of any of Articles FI 1-FI 6, wherein power take off is performed using a gear, and the ring contains holes for engaging the gear.

FI 9. The method of any of Articles FI 1-FI 6, wherein power take off is performed using friction.

F20. The method of any of Articles FI 1-FI 6, wherein the blade pitch is governed by an electronic control system.

G21. An axial flow wind turbine rotor, comprising:

a rotating;

a plurality of airfoil blades, coupled to the hub;

each blade is supported by at least one external cable;

a ring, coaxial to the wind rotor, external to the hub, attached to the wings;

the ring being adapted to engage a rotational element, coupled to a rotor of an electrical generator.

H22. A wind turbine, comprising a tower; a nacelle on top of the tower, the nacelle being capable of rotating at least 360 degrees in horizontal plane; a wind rotor of axial flow type, coupled to the nacelle; characterized in that the tower is

supported by guy wires above the rotor line and the wind rotor is tilted to vertical to avoid hitting the guy wires.

H23. The wind turbine of Article H22, wherein the rotor is downwind from the tower.

H24. The wind turbine of Article H22, wherein the rotor is upwind from the tower.

H25. The wind turbine of any of Articles H22-H24, wherein the tower is of lattice type.

H26. The wind turbine of Article H23, wherein the tower is floating.

US Provisional Patent Application 62/021,662 is incorporated here by reference, with the correction that an example tower height is 100 m (not 10 m), and in case of any conflicting term definitions or meanings the meaning or the definition of the term from this disclosure applies. The following article by the inventor helps in understanding some of the embodiments:

A proposal and a theoretical analysis of a novel concept of a tilted-axis wind turbine, Leonid Goldstein, Energy Journal, 84, pp. 247-254,

<http://dx.doi.org/10.1016/j.energy.2015.02.110>

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate the invention. The illustrations omit details not necessary for understanding of the invention, or obvious to one skilled in the art, and show parts out of proportion for clarity. In such drawings:

Fig. 1 shows a side view of the wind turbine according to one embodiment of the invention, with two out of four blades not shown.

Fig. 2 shows an electrical generator and its coupling to the power take off ring.

Fig. 3A shows the wind rotor, viewed along its axis upwind.

Fig. 3B shows the wind rotor, viewed from above along the plane of rotation.

Fig. 4.1 shows a side view of another embodiment, having a more traditional axial power take off.

Fig. 4.2 shows a side view of a similar embodiment with a rotor above the tower.

Fig. 5 shows an embodiment, similar to one in Fig. 4A, in an offshore environment.

Fig. 6 shows a side view of a wind turbine with a tilted rotor of conventional type.

Fig. 7 shows details of the cables attachment to the main shaft, viewed from the center of the rotor in Fig. 4.1.

Fig. 8A shows a top view in the plane of rotation of an improvement to one of the above embodiment, comprising a torque compensating airfoil.

Fig. 8B shows a side view of the same improvement.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a side view of the wind turbine according to one embodiment of the invention, with two blades not shown. The embodiment comprises a tower 101, which is supported by three to six guy wires 102, attached at the top of the tower. Instead of a traditional nacelle, there is a rotor base 103 on the top of tower 101, installed on a yawing platform 104. An axle 105 is attached to the base at an angle 5-45 degrees to the horizon (preferably 15-30 degrees). A wind rotor 106

is installed on axle 105 downwind of tower 101. Rotor 106 comprises multiple airfoil blades 108 that are attached to axle 105 on spars 109. In this example, there are four blades, only two of them are shown in Fig. 1. Each blade 108 is supported by one or more cables 110. One end of cable 110 is attached to blade 108, while another end is attached to a power take off ring 112, co-axial with axle 105. Ring 112 is attached to axle 105 by cables 111 and rotates with rotor 106. Cable 110 attachments to blades 108 should not prevent blades 108 from pitching. Cables 110 are pre-stressed. Thus, cables 110 resist most of the wind pressure, acting on the blades when the rotor rotates in the wind, while back tension of spars 109 and blades 108 themselves prevents occasional moves of blades 108 in the opposite direction (back flapping). (Alternatively, axle 105 can be extended beyond the plane of the blades and additional cables attached to the blades from the end of axle 105.) Ring 112 serves for power take off. Electrical generators 113 are attached to rotor base 103, preferably with triangular or truss-like structural members. One electrical generator 113 is shown on Fig. 1. This attachment does not rotate with rotor 106. Generator 113 takes off power from ring 112 using a gear 114, engaging the ring as shown in Fig. 2. When the wind rotates wind rotor 106, electrical generators 113 produce electricity, which is sent to the consumers over wires. A counterweight 115 is installed on a counterweight arm 116, attached to the opposite end of axle 105, bringing the center of gravity of the assembly with the rotor to the centerline of tower 101. In any case, counterweight 115 and counterweight arm 116 must be above the line of guy wires and not to collide with them. Blades 108 are preferably pitch controlled. An electronic control system 117 is provided to control at least the

pitch of blades 108. It can also control the drivetrain and other aspects of the wind turbine.

Fig. 2 shows elements of the drivetrain with its coupling to power take off ring 112, including electrical generator 113, gear 114 and a section of ring 112.

Electrical generator 113 comprises an electric rotor 201 and a stator 202. The rotor of electrical generator 113 is rotationally coupled to gear 114. Ring 112 is equipped with teeth or holes or recesses, allowing it to engage gears 114.

(Alternatively, a rubber tire or a wheel can be used instead of gear 114, in which case ring 112 is covered with rubber; other high friction material can be used instead of the rubber.) There is an optional roller 203, attached to the housing of electrical generator 113, which presses gear 114 down to ring 112. There may be springs or other devices, allowing some "play" for wheel or gear 114 to accommodate flexing of ring 112.

Fig. 3A shows the wind rotor and gears 114, viewed from the rotor axis upwind. It shows four blades 108, and a clear view of ring 112. Further, it shows cables 111 and 110. Cables 110 are attached to ring 112 with an offset of 5-10 degrees along the circle to allow them to transfer not only wind lift component, perpendicular to the plane of rotation, but also useful torque (in the plane of rotation). Multiple supporting cables 110 can be attached to a single blade 108 in different points along its span for better support. The arrow shows the direction of rotation of the rotor. Spars 109 are optional - blades 108 can be attached directly to axle 105.

Fig. 3 B shows the wind rotor, gears 114 and their attachment to rotor base 103, viewed from above in the plane of rotation.

In principle, wheels or gears 114 can be installed on any side of ring 112. It might be preferable to have at least three wheels or gears 114 contacting ring 112 at equal distance from each other.

The wind turbine, described above, presents a number of synergetic advantages over a conventional horizontal axis wind turbine (HAWT). Moreover, it defies the conventional thinking in the wind energy industry. It is well known, that guy wires are not used in the modern HAWT, because they would collide with the rotor blades. When the guy wires were used, they were attached to the tower well below the rotor lines. Further, it is considered desirable to have the rotor to rotate in the vertical plane perpendicular to the direction of the wind, in order to maximize the swept area. The proposed wind turbine defies these considerations, and achieves surprising benefits. The downwind rotor, tilted to the vertical plane as shown in the figures, allows use of guy wires to support the tower at or near the top. The guy wires compensate most or all of the bending force acting on tower as result of the wind pressure on the wind rotor. It should be noted that this bending force is the main factor determining the required strength of the tower. Only a fraction of the tower strength is needed to support the weight of the top of the tower structure of HAWT. The angle of the rotor to the vertical line further decreases the compressive forces, acting on the tower. If the angle of the rotor axis to the horizon is the same as the angle of the guy wires, the guy wires compensate most of wind pressure on the rotor (fully compensate it when the

rotor axis is aligned with a guy wire). Further, the rotor, tilted to the vertical, may have radius, larger than height of the tower, and sweep larger area in the plane, perpendicular to the wind. The center of the rotor is elevated above the top of the tower, allowing to make the tower shorter for the same rotor height and sweep. Thus, the tower can be cheaper and lighter than in case of HAWT with comparable power. A lattice tower may be used. The blades rotate far from the tower, and the tower is narrow or lattice tower, so the blades do not pass in the shadow of the tower - the described wind turbine does not suffer from the effect that doomed the conventional wind turbines with downwind rotor in the past. Further, it is expected that the described tilt of the rotor will accelerate the flow of the air in the lower part of the swept area. This effect is highly beneficial, because the wind speed is usually lower at lower heights, causing rotor imbalance and loss of power. Further, the rotor blades resist aerodynamic lift through tension of supporting cables 110, compared to the bending forces, experienced by blades of conventional HAWT. Supporting cables 110 and cables 111 and can be made of synthetic fiber materials (ultra-high molecular weight polyethylene fiber, para-aramids, carbon fibers etc.) with excellent specific strength. That allows to make the blades lighter, cheaper, shallower and better optimized for high lift/drag ratio. The suspension cables are attached to the blade in one or more points along its length, preferably at or around the center of the aerodynamic pressure. Spars 109 are also light and thin. Thus, the rotor is light and does not subject axle 105 to large forces. This quality, in turn, allows to move blades further away from the tower to improve angles of the suspension cables. Cables 110 are attached to ring 112 and allow to take off the harvested power off ring 112. Ring 112 may

have diameter from $1/12$ to $2/3$ diameter of the rotor. Preferably, the ring diameter is $1/6$ to $1/2$ diameter of the rotor. Power take off of the ring allows to achieve high rotation frequency (1,500-1,800 RPM) of the rotor of the electrical generator without employing a gearbox, achieving further cost savings and reduction in weight. Ring 112 can be made of steel, aluminum, high strength polymers, carbon fiber etc. Ring 112 can be exposed or covered. Ring 112 can be made of steel strappings or flexible ribbon or strap. Fig. 1 shows the power removal surface of ring 112 external and perpendicular to the plane of rotation, but it can be internal, or angled or parallel to the plane of rotation (with appropriate change in location of gears and generators). Optionally, ring 112 can be in the plane of the blades rotation. The number of electrical generators may be from one to twelve, although the optimal number is from three to six. Number of blades can be from two to twelve, but the optimum number of blades is three or four. All the ranges are inclusive. Pylons or other rigid members can be used instead of cables 110. These pylons can have an aerodynamically streamlined profile. Tower 101 can have vertical ribs to prevent buckling.

The wind turbine, described above, is lighter, cheaper and has lower visual impact than a conventional HAWT of the same power. The transportation and installation are also less expensive. In aspects, not described above, this wind turbine may borrow from conventional HAWT. End of the counterweight arm is a good place for an anemometer. Blade pitch may be changed as the blade moves in the circle ("cyclic"). One preferred strategy, executed by the control system, is to change the pitch cyclically to eliminate the horizontal moment, acting on the rotor

because of different relative air speed on the right and left sides of the rotor, and to maximize the produced power (after eliminating the horizontal moment). In the system described above, rotor base 103 may be allowed to rock in the vertical plane, with the angle of axle 105 to the horizon increasing with increase in wind speed and decreasing with decrease in wind speed. Also, the rotor can have a conical form (in rotation), with the blades deflected forward or backward. Besides being deflected by wind, the blades can be deflected by the control system, for example, to eliminate the horizontal moment. Further, each blade can be composed of two or more sections of different average thickness and chord, connected by their ends, and capable of pitching at different angles (independent pitching). The rotor can have any number of blades, but three to six blades seem preferable. Further, the blades can have different sizes (example: 3 long blades and 3 short ones).

Example system parameters: tower height - 100m; rotor diameter - 150m; ring 112 diameter - 50m; rotor tilt angle - 25° ; number of guy wires - 4; guy wire angle to the horizon - 35° .

A possible alternative for the contact ring is a roller chain or a perforated belt. If the roller chain is used, the gear 114 is replaced by a sprocket, engaged by the chain. The chain can have other than circular form. Axle 105 can be replaced with a non-rotating vertical truss, to which the rotating parts are attached on appropriate roller bearings.

In another preferred embodiment, the rotor axis is substantially horizontal, and the guy wire angle to the horizon is 45° . The tower will be subjected to more

vertical load, and the system may need longer axle 105 or smaller rotor diameter, but the rotor does not experience horizontal moment and does not need continuous control input to compensate for this moment. This embodiment may be easier for the industry to adopt.

Fig. 4.1 shows another embodiment of the invention with a conventional power take off through a main shaft. In this embodiment, a nacelle 401, containing a gearbox 402 and an electrical generator 403, is installed on top of yawing mechanism 104 on top of tower 101. (Alternatively, a combination of gearbox 402 and electrical generator 403 can be replaced by a direct drive generator.) Tower 101 is supported by guy wires 102. A main shaft 405 has a rotor 406 on its end. Rotor 406 is downwind from tower 101. Nacelle 401 is offset upwind to serve as a counterweight to rotor 406. (Alternatively, it may be downwind or on top on the tower, with a counterweight upwind, as in the embodiment from Fig. 1.) Main shaft 405 is tilted to the horizontal plane. Rotor 406 has blades 408 (preferably two to six; two in Fig. 4.1), installed on spars 407. Blades 408 are supported by cables 409, similarly to the embodiment in Fig. 1. Preferably, cables 409 resist most of the aerodynamic forces, experienced by blades 408, and are coupled to shaft 405 through a ring 412 in such a way as to transfer at least some of torque. **Fig. 7** shows details of the cables attachment to the main shaft, viewed from the center of the rotor in Fig. 4.1. The error shows direction of rotation of ring 412 and shaft 405.

In Fig. 4.1, guy wires 102 and main shaft 405 have similar angles to the horizon. That eliminates bending momentum and most of compression from tower 101. Thus, tower 101 needs to support only the weight of the nacelle and the rotor. This system has most of the benefits of the system in Fig. 1, except that it requires a gearbox. On the other hand, it is more traditional and easier for industry to adopt. Multiple rotors can be installed on a single tower, possibly at angle to each other.

In another preferred embodiment, the rotor axis is substantially horizontal, and the guy wire angle to the horizon is 45° . This embodiment may need longer axle 405 or smaller rotor diameter, but the rotor does not experience horizontal moment and does not need continuous control input to compensate for this moment. This embodiment may be easier for the industry to adopt.

Another embodiment of the invention is a wind turbine with a rotor which is neither downwind nor upwind, but above the tower. Such wind turbine is shown in **Fig. 4.2**. It is similar to one from Fig. 4.1, except that rotor 406 sits on an axle 411, which is born by a member 410, which sits on top of yawing mechanism 104. Axle 411 freely rotates relative to both member 410 and nacelle 401. The center of rotor 406 is above the centerline of tower 401. In Fig. 4B, nacelle 401 is upwind from rotor 406, but it can be downwind from it as well. The embodiment from Fig. 1 can be modified with the rotor above the tower, too. Placement above the tower gives additional elevation to the rotor, although at the cost of additional weight and expense of the truss or a similar load bearing member.

The wind turbines, described in Fig. 1 - 4.1 are especially suitable for placement offshore in deep waters. They can be placed on floating platforms. **Fig. 5** shows a variation of the wind turbine from Fig. 4, where tower 101 is supported by a buoy 501. Buoy 501 provides sufficient buoyancy to support weight of the tower with the turbine and to resist any additional vertical forces (if occur), resulting from the wind pressure on the rotor. Buoy 501 is held in place by chains 502. Chains 502 as well as guy wires 102 are attached to bottom anchors 503. Bottom anchors 503 are preferably of suction type.

Fig. 6 shows another embodiment of the invention, in which a conventional downwind rotor 602 is installed at an angle on top of tower 101, supported by guy wires 102. The rotor's plane inclination gets the rotor away from the guy wire and decreases compressive forces on the tower, resulting from the combination of the wind pressure and guy wire tension. This wind turbine also has benefits of the wind turbines with downwind rotor, while avoiding their main deficiency - blades passing in the aerodynamic shadow of the tower. The figure also shows a nacelle 601. This embodiment can be beneficially practiced on the land or off-shore, especially on floating wind turbines.

For higher power production and simpler control system operation it might be beneficial to provide most of horizontal moment compensation not through pitching of the blades in the embodiments above. One of the ways to achieve that is shown in **Fig. 8A** (top view in the plane of rotation) and **Fig. 8B** (side view). A vertical airfoil 801 is provided, attached to axle 105. To ensure that it remains vertical, it is installed on axle 105 on roller bearings 802 and its lower end is

weighted. In the wind, airfoil 801 creates lift perpendicular to its cord, in direction, compensating the moment of the rotor. Airfoil 801 is attached to bearings 802 by a stem 803. It can be equipped with an actuator 803, changing angle of attack of airfoil 801. Airfoil 801 compensates all or most of the moment, so that blades pitch is optimized to maximize power production, rather than to eliminate the moment.

In the embodiments described above, blades 108 and/or 408 can have inverted gull wing form and/or have wing tips in order to increase captured power while maintaining clearance from the guy wires.

Thus, a device and a method for a structurally optimized tilted or horizontal axis wind turbine have been disclosed with one or more specific embodiments. While above description contains many specificities, these should not be construed as limitations on the scope, but rather as exemplification of several embodiments thereof. Many other variations are possible and contemplated.

WHAT IS CLAIMED IS:

[Claim 1] A wind turbine, comprising:

a tower,

an axial flow wind rotor, installed on the tower;

a plurality of guy wires, supporting the tower;

where the guy wires are attached to the tower above the rotor line;

and

the wind rotor's axis tilted in the vertical plane in such a way that

the tower's centerline crosses said rotation plane above the tower.

[Claim 2] The wind turbine of Claim 1, wherein the guy wires are attached near the top of the tower.

[Claim 3] The wind turbine of any of Claims 1-2, wherein the wind rotor is downwind from the tower.

[Claim 4] The wind turbine of Claim 3, wherein the wind rotor is counterweighted.

[Claim 5] The wind turbine of any of Claims 1-2, wherein the wind rotor is above the tower.

[Claim 6] The wind turbine of any of Claims 1-5, further comprising an underground foundation for the wind turbine.

[Claim 7] The wind turbine of any of Claims 1-5, further comprising a buoy, allowing the wind turbine to float.

[Claim 8] The wind turbine of Claim 7, wherein the wind turbine is floating in a sea or ocean and the guy wires are anchored at the bottom of the sea or ocean.

[Claim 9] The wind turbine of any of Claims 1-8, wherein the tower is of lattice type.

[Claim 10] The wind turbine of any of Claims 1-9, wherein the angle between the wind rotor's rotation plane and the vertical is between 15 and 45 degrees, inclusive.

[Claim 11] The wind turbine of any of Claims 1-9, wherein the wind rotor's axis is substantially horizontal.

[Claim 12] The wind turbine of any of Claims 1- 11, wherein the angle between the wind rotor's rotation plane and the vertical is substantially equal to the angle between at least one of the guy wires and the horizontal plane.

[Claim 13] The wind turbine of any of Claims 1- 12, wherein the rotor blades are supported by external cables in order to decrease their weight.

[Claim 14] The wind turbine of any of Claims 1- 13, wherein the guy wires are designed to compensate at least most of the horizontal pressure, exerted by the wind on the wind rotor in operation.

[Claim 15] The wind turbine of any of Claims 1- 14, further comprising an electronic control system, adapted to continuously change pitch of the

rotor blades to minimize undesirable horizontal moment of force, acting on the rotor.

[Claim 16] A method of converting wind energy into electrical energy, comprising:

providing a tower;

installing an axial flow wind rotor on top of the tower at an angle to the vertical;

supporting the tower with a plurality of guy wires, attached to the tower above the rotor line;

wherein the lower part of the wind rotor is turned away from the tower.

[Claim 17] The method of Claim 16, wherein the guy wires are attached near the top of the tower.

[Claim 18] The method of any of Claims 16-17, wherein the wind rotor is placed downwind from the tower.

[Claim 19] The method of Claim 18, wherein the wind rotor is counterweighted.

[Claim 20] The method of any of Claims 18-19, wherein the wind rotor is placed above the tower.

[Claim 21] The method of any of Claims 16-20, further comprising attaching the tower to an underground foundation.

[Claim 22] The method of any of Claims 16-20, further comprising attaching the tower to a buoy, allowing the wind turbine to float.

[Claim 23] The method of Claim 22, wherein the wind turbine is floating in a sea or ocean and the guy wires are anchored at the bottom of the sea or ocean.

[Claim 24] The method of any of Claims 16-23, wherein the tower is of lattice type.

[Claim 25] The method of any of Claims 16-24, wherein the angle between the wind rotor's rotation plane and the vertical is predefined and is between 5 and 45 degrees, inclusive.

[Claim 26] The method of any of Claims 16-24, wherein the wind rotor's axis is substantially horizontal.

[Claim 27] The method of any of Claims 16-24, wherein the angle between the wind rotor's rotation plane and the vertical is kept substantially equal or less than the angle between at least one of the guy wires and the horizontal plane.

[Claim 28] The method of any of Claims 16-27, wherein the rotor blades are supported by external cables in order to decrease their weight.

[Claim 29] The method of any of Claims 16-28, wherein the guy wires compensate at least most of the horizontal pressure, exerted by the wind on the wind rotor in operation.

[Claim 30] The method of any of Claims 16-28, wherein the pitch of the rotor blades is continuously controlled to maximize the power production.

[Claim 31] A wind turbine comprising:

a wind rotor having a plurality of radial airfoil blades;
each blade being supported by at least one external cable; and
at least one drivetrain, coupled to the wind rotor, the drivetrain is adapted for power take-off from either mid-rotor or rotor periphery.

[Claim 32] The wind turbine of Claim 31, wherein the power take-off is mid-rotor.

[Claim 33] The wind turbine of Claims 31-32, wherein each blade is attached to the rotor by a spar.

[Claim 34] The wind turbine of any of Claims 31-33, further comprising a contact ring for power take-off, coaxial to the wind rotor.

[Claim 35] The wind turbine of Claim 31-34, wherein the contact ring touches the blades or the spars.

[Claim 36] The wind turbine of Claim 34, wherein at least some external cables are attached to the contact ring.

[Claim 37] The wind turbine of any of Claim 34, wherein the contact ring is attached to the rotor.

[Claim 38] The wind turbine of any of Claims 31-37, wherein the contact ring has teeth or recesses and the drivetrain comprises a gear, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator.

[Claim 39] The wind turbine of any of Claims 31-37, wherein the drivetrain comprises a tire, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator; and the contact ring's surface has high friction coefficient with the tire.

[Claim 40] The wind turbine of any of Claims 31-33, wherein the contact ring has teeth or recesses and the drivetrain comprises a gear, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator.

[Claim 41] The wind turbine of any of Claims 31-33, further comprising a chain or a belt for power take-off, the chain or belt is coupled to at least two blades.

[Claim 42] The wind turbine of Claim 33, further comprising a chain or a belt for power take-off, the chain or belt is coupled to at least two spars.

[Claim 43] The wind turbine of any of Claims 41-42, wherein the drivetrain comprises a sprocket, engaging the chain or belt; and an electrical generator; the gear sprocket is rotationally coupled to the rotor of the electrical generator.

[Claim 43] A method of converting wind energy into electrical energy, comprising:

providing a tower with a wind rotor, having a plurality of radial airfoil blades;

supporting each blade against aerodynamic forces with at least one external cable;

performing mechanical power take-off from either mid-rotor or rotor periphery.

[Claim 45] The method of Claim 44, wherein the power is taken-off mid-rotor.

[Claim 46] The method of Claims 44-45, wherein each blade is attached to the rotor by a light weight spar.

[Claim 47] The method of any of Claims 44-46, wherein the power is taken off of a contact ring, coaxial to the wind rotor.

[Claim 48] The method of Claim 47, wherein the contact ring touches the blades or the spars.

[Claim 49] The method of Claim 47, wherein at least some external cables are attached to the contact ring.

[Claim 50] The method of any of Claims 47-48, wherein the contact ring is attached to the rotor.

[Claim 51] The method of any of Claims 44-50, wherein the contact ring has teeth or recesses and the drivetrain comprises a gear, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator.

[Claim 52] The method of any of Claims 44-50, wherein the drivetrain comprises a tire, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator; and the contact ring's surface has high friction coefficient with the tire.

[Claim 53] The method of any of Claims 44-46, wherein the contact ring has teeth or recesses and the drivetrain comprises a gear, engaging the contact ring; and an electrical generator; the gear being rotationally coupled to the rotor of the electrical generator.

[Claim 54] The method of any of Claims 44-46, where in the power take-off is performed via a chain or a belt, the chain or belt being coupled to at least two blades.

[Claim 55] The method of Claim 46, wherein the power take-off is performed via a chain or a belt, the chain or belt is coupled to at least two spars.

[Claim 56] The method of any of Claims 54-55, wherein the drivetrain comprises a sprocket and an electrical generator, the sprocket being

rotationally coupled to the rotor of the electrical generator; and the chain or belt engage the gear.

[Claim 57] A wind turbine, having a tower and an assembly, installable on top of the tower, the assembly comprising:

a base, capable of horizontal rotation on the tower;

an axial flow wind rotor, comprising:

a rotating hub;

a plurality of airfoil blades, coupled to the hub;

each blade is supported by at least one external cable;

a ring, external to the hub, coaxial to the wind rotor.

at least one drivetrain assembly, comprising:

an electrical generator with an electric rotor and a stator;

a rotational element, engaging the ring and rotationally coupled to the rotor of the electrical generator for power take off from the ring.

[Claim 58] The system of Claim 57, where the tower is supported by three or more guy wires above the rotor line.

[Claim 59] The system of Claim 58, where the tower is placed in a natural water body, while the guy wires are anchored at the bottom.

[Claim 60] The system of any of Claims 57-59, wherein the axis of the wind rotor is tilted in the vertical plane.

[Claim 61] The system of any of Claims 57-60, where the wind rotor is downwind from the tower.

[Claim 62] The system of any of Claims 57-61, where a counterweight is attached to the base.

[Claim 63] The system of any of Claims 57-62, where the rotational element is a gear.

[Claim 64] The system of any of Claims 57-63, where the rotational element is a tire.

[Claim 65] The system of any of Claims 57-64, comprising at least two drivetrains.

[Claim 66] The system of any of Claims 57-65, wherein the tower is of lattice type.

[Claim 67] A method of converting wind power into electrical power, comprising steps of:

harvesting wind power using an axial flow wind rotor, comprising:

a rotating hub, installed on top of a tower;

plurality of airfoil blades, coupled to the hub;

a ring, coaxial to the wind rotor, external to the hub, attached to the wings;

using at least one external cable to support each blade;

taking the harvested power off the ring and converting it to electrical power using an electrical generator.

[Claim 68] The method of Claim 67, wherein the ring rotates horizontally, following changes in the direction of the wind.

[Claim 69] The method of any of Claims 67-68, wherein the wind rotor is tilted upwind.

[Claim 70] The method of any of Claims 67-69, wherein the tower is supported by three or more guy wires.

[Claim 71] The method of any of Claims 67-70, wherein the tower is floating.

[Claim 72] The method of any of Claims 67-71, wherein the rotor is counterweighted.

[Claim 73] The method of any of Claims 67-72, wherein power take off is performed using a gear, and the ring is equipped with teeth for engaging the gear.

[Claim 74] The method of any of Claims 67-73, wherein power take off is performed using a gear, and the ring contains holes for engaging the gear.

[Claim 75] The method of any of Claims 67-74, wherein power take off is performed using friction.

[Claim 76] The method of any of Claims 67-75, wherein the blade pitch is governed by an electronic control system.

[Claim 77] An axial flow wind turbine rotor, comprising:

a rotating;

a plurality of airfoil blades, coupled to the hub;

each blade is supported by at least one external cable;

a ring, coaxial to the wind rotor, external to the hub, attached to the wings;

the ring being adapted to engage a rotational element, coupled to a rotor of an electrical generator.

[Claim 78] A wind turbine, comprising a tower; a nacelle on top of the tower, the nacelle being capable of rotating at least 360 degrees in horizontal plane; a wind rotor of axial flow type, coupled to the nacelle; characterized in that the tower is supported by guy wires above the rotor line and the wind rotor is tilted to vertical to avoid hitting the guy wires.

[Claim 79] The wind turbine of Claim 78, wherein the rotor is downwind from the tower.

[Claim 80] The wind turbine of Claim 79, wherein the rotor is upwind from the tower.

[Claim 81] The wind turbine of any of Claims 78-80, wherein the tower is of lattice type.

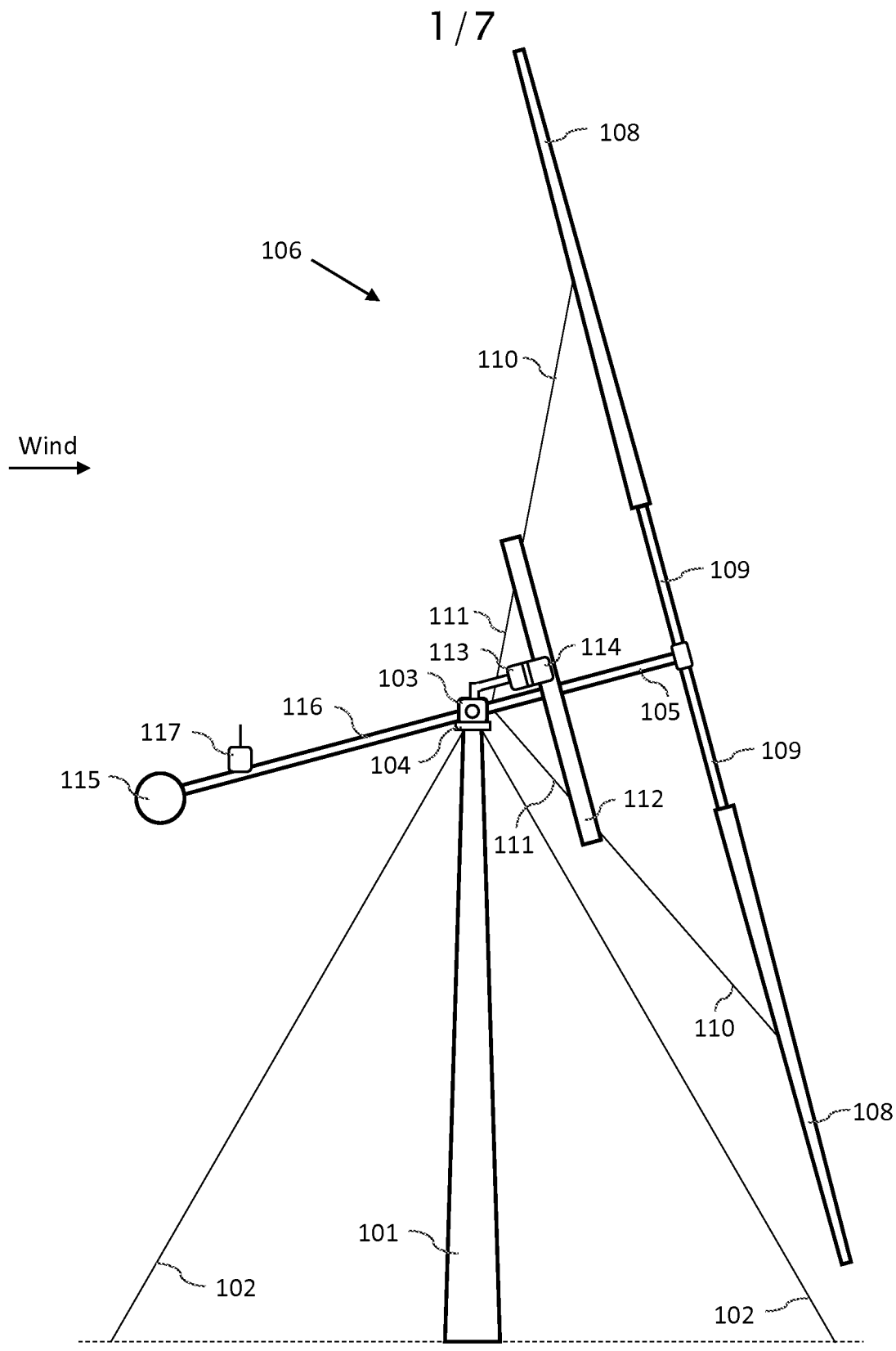


Fig. 1

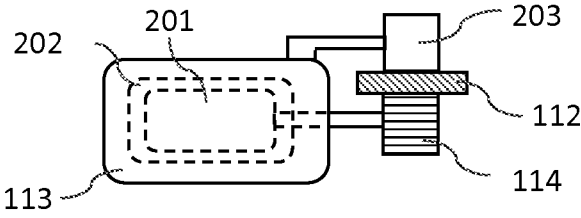


Fig. 2

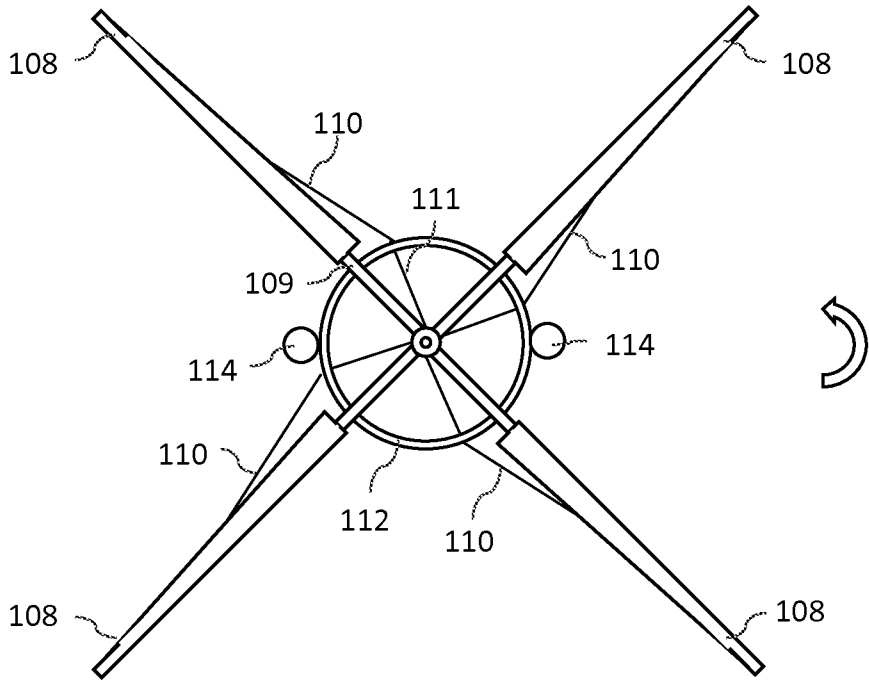


Fig. 3A

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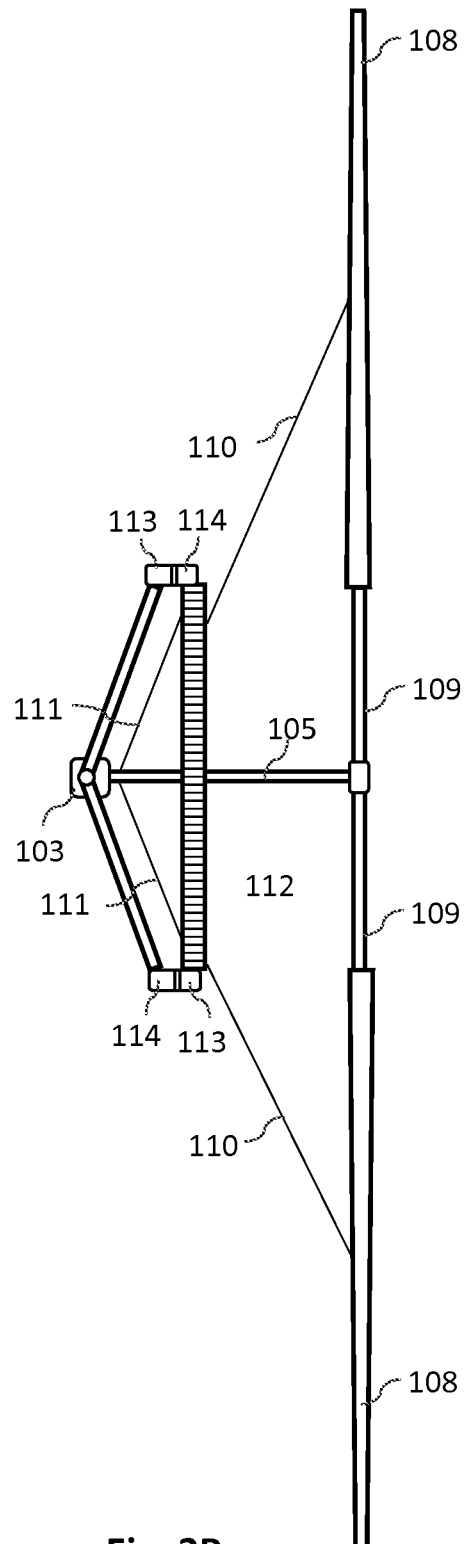


Fig. 3B

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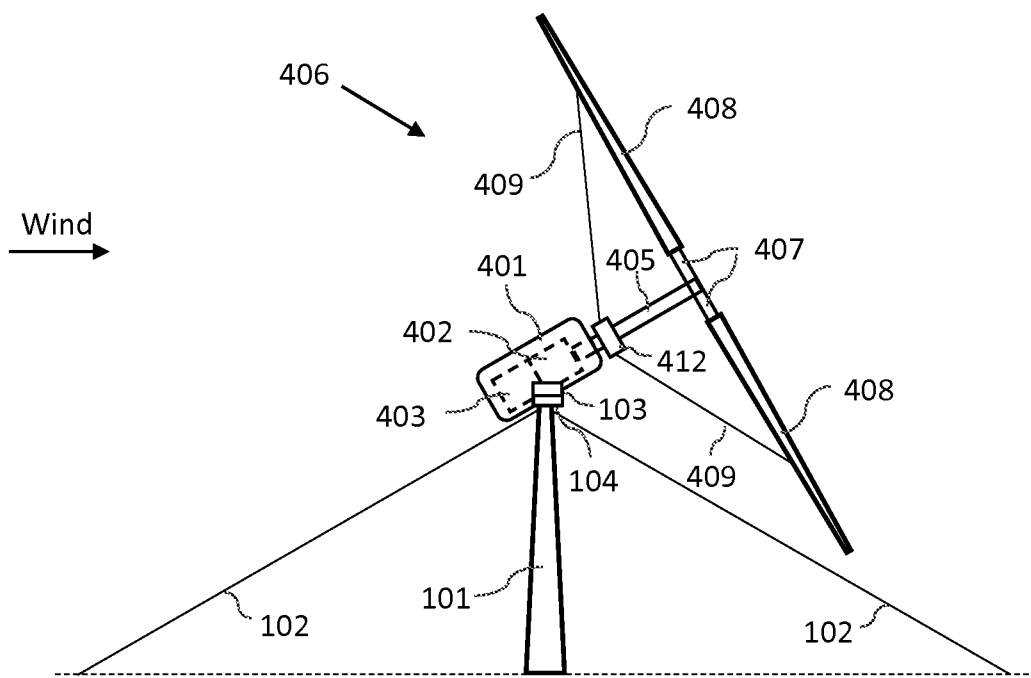


Fig. 4.1

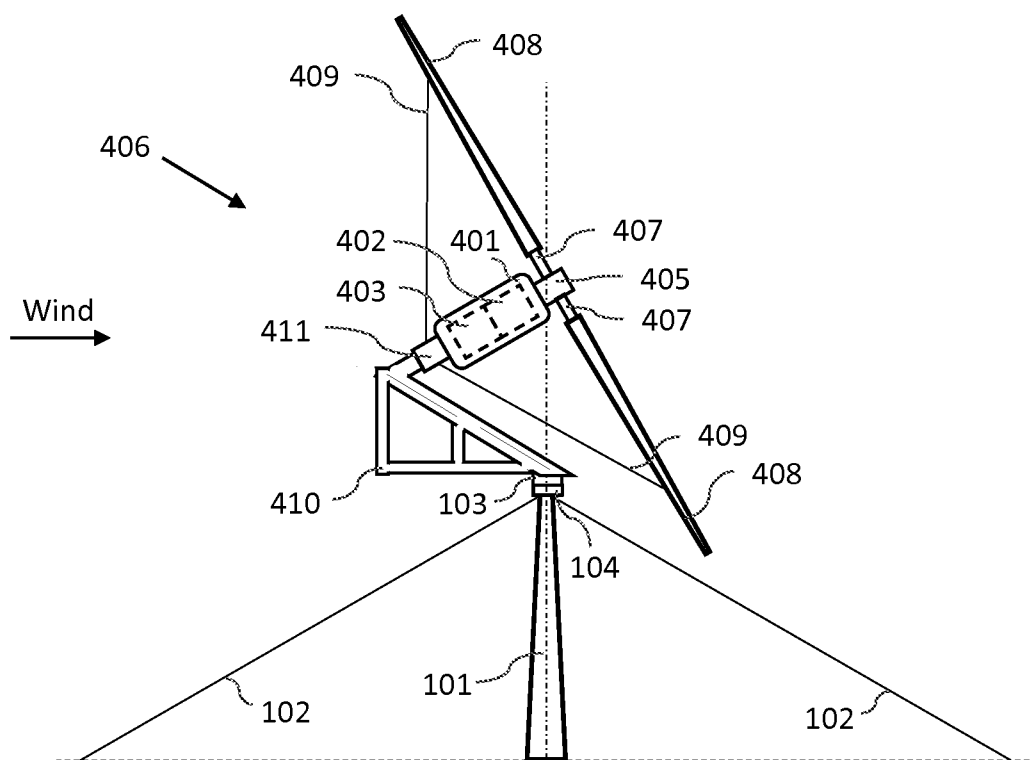


Fig. 4.2

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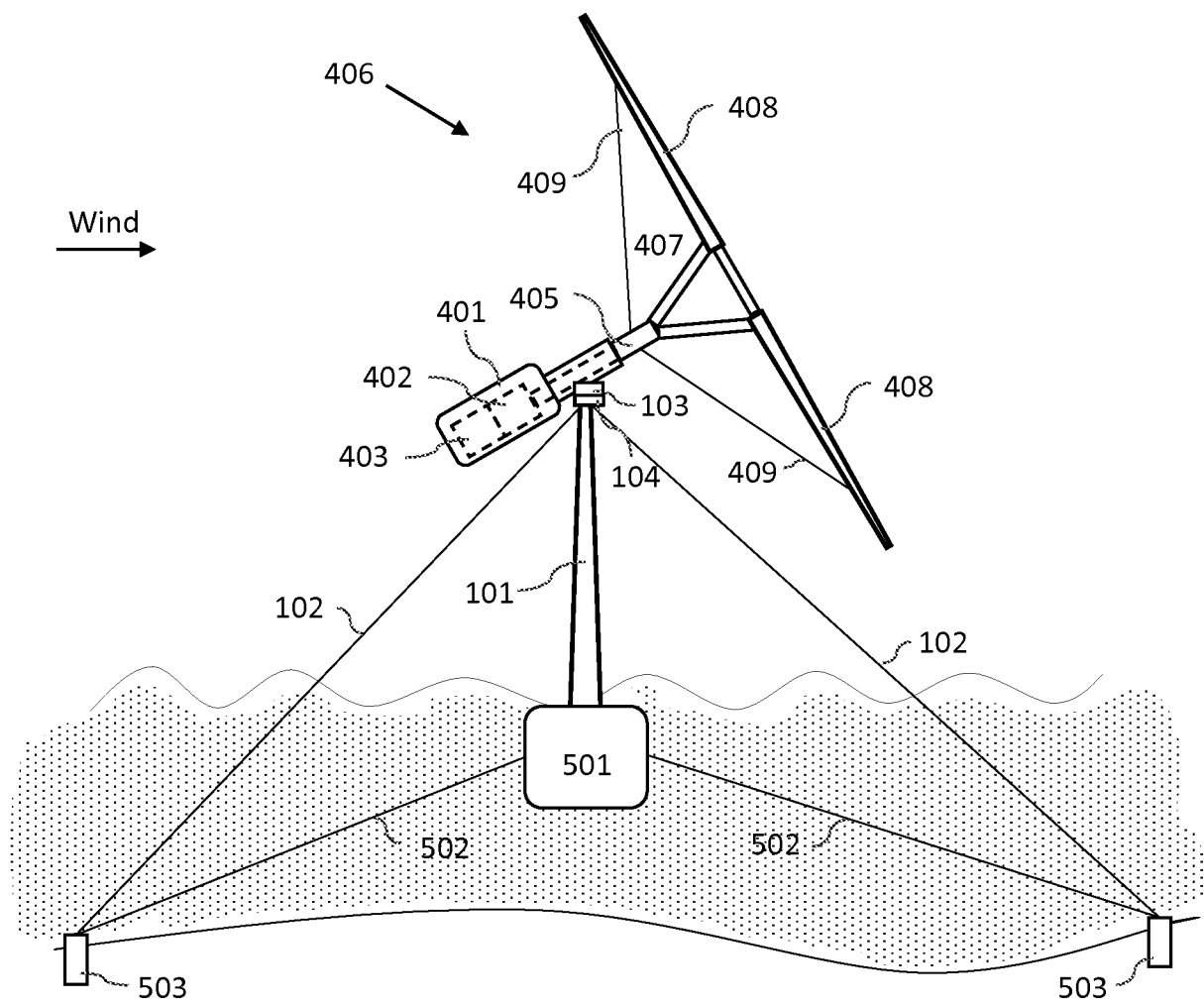


Fig. 5

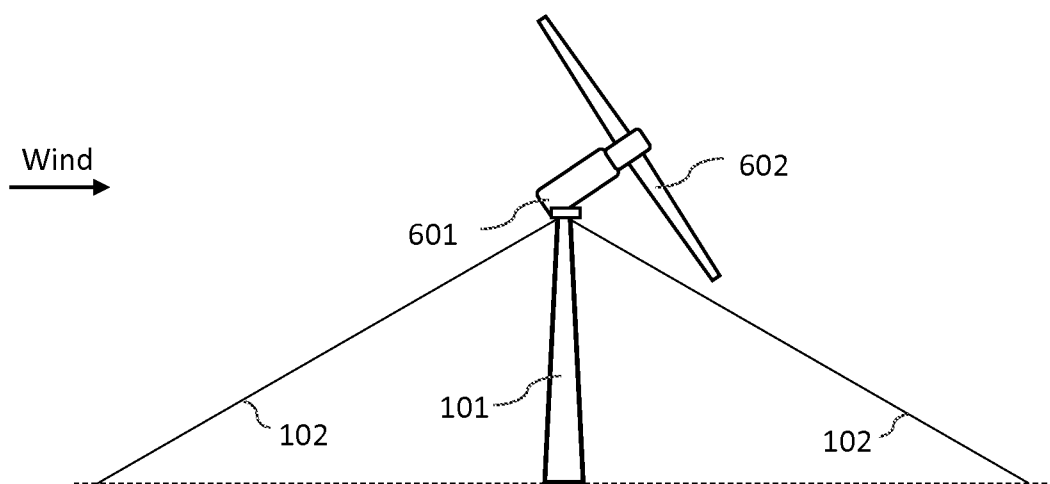


Fig. 6

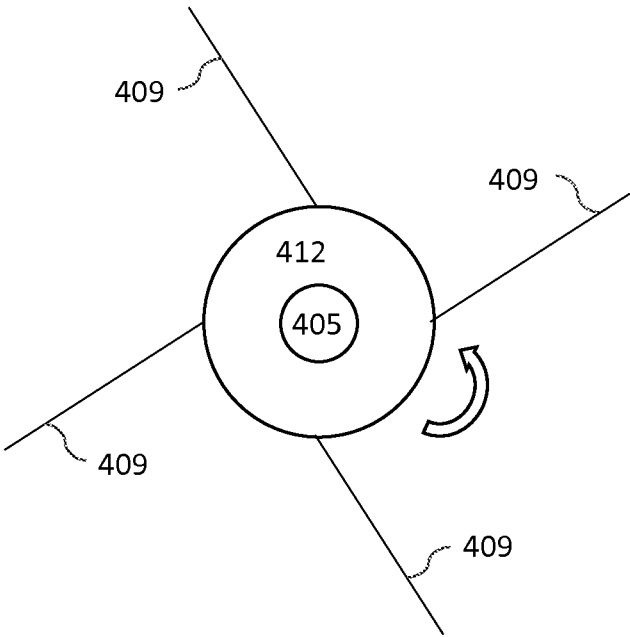


Fig. 7

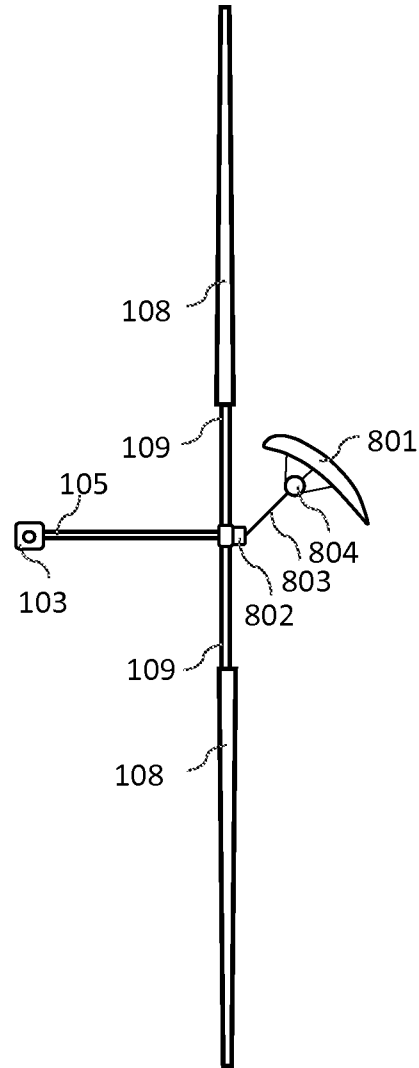


Fig. 8A

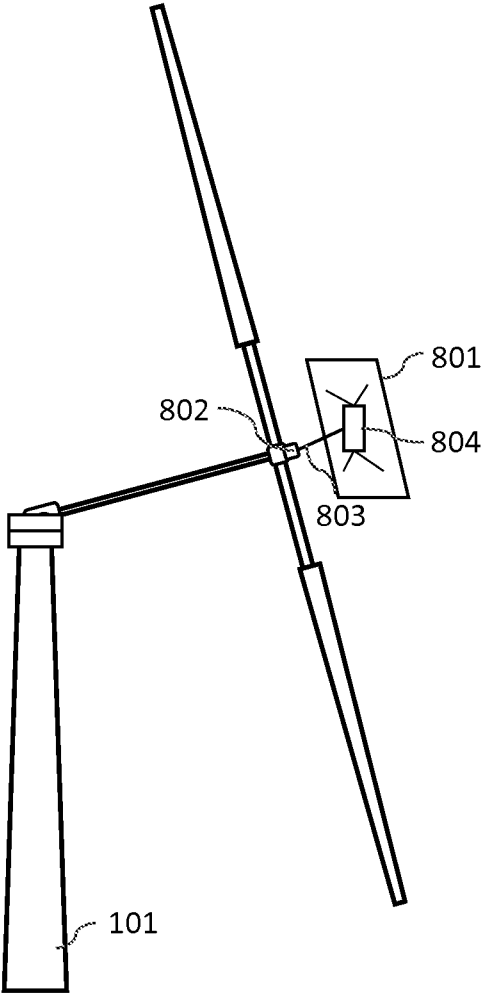


Fig. 8B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US1 5/27874

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F03D 7/00, 7/02, 7/06 (2015.01)

CPC - F03D 7/0244; Y02E 10/72, 10/726

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) Classification(s): F03D 1/00, 3/06, 7/00, 7/02, 7/06, 11/00, 11/04 (2015.01); USPC Classification(s): 416/1, 416/147

CPC Classification(s): F03D 7/0244; Y02E 10/70, 10/72, 10/721, 10/722, 10/723, 10/725, 10/726, 10/728, 10/74

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data): wind, turbine, tower, rotor, nacelle, guy, stabilize, support, wires, cable, lattice, axial, 360 degrees, upwind, downwind, upstream, downstream, rotate, pivot, counterweight, counterbalance, weight, balance, tilting, angling, vertical

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,979,175 B2 (DRAKE D. G.) December 27, 2005; figures 1, 4; column 4, lines 60-65, column 5, lines 1-10	1, 2, 3/1, 3/2, 4/3/1, 4/3/2, 5/1, 5/2, 16, 17, 18/16, 18/17, 19/18/16, 19/18/17
Y		78, 79, 80, 81/78-81/80
Y	US 5,213,470 A (LUNDQUIST R. E.) May 25, 1993; column 4, lines 55-60, column 15, lines 10-15	78, 79, 80, 81/78-81/80
X	US 2005/02141 17 A1 (SELSAM D. S.) September 29, 2005; abstract; figures 1-5; paragraphs [0048], [0049]	1, 2, 3/1, 3/2, 4/3/1, 4/3/2, 5/1, 5/2, 16, 17, 18/16, 18/17, 19/18/16, 19/18/17
A	US 6,800,956 B2 (BARTLETT L. P.) October 05, 2004; entire document	1, 2, 3/1, 3/2, 4/3/1, 4/3/2, 5/1, 5/2, 16, 17, 18/16, 18/17, 19/18/16, 19/18/17, 78, 79, 80, 81/78-81/80
A	WO 201 1/146773 A2 (CATADON SYSTEMS, INC.) 24 November 2011; entire document	1, 2, 3/1, 3/2, 4/3/1, 4/3/2, 5/1, 5/2, 16, 17, 18/16, 18/17, 19/18/16, 19/18/17, 78, 79, 80, 81/78-81/80



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

03 September 2015 (03.09.2015)

Date of mailing of the international search report

30 SEP 2015

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Shane Thomas

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US15/27874

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,320,273 B1 (NEMEC O.) November 20, 2001; entire document	1, 2, 3/1, 3/2, 4/3/1, 4/3/2, 5/1, 5/2, 16, 17, 18/16, 18/17, 19/18/16, 19/18/17, 78, 79, 80, 81/78-81/80
A	US 2010/0143138 A1 (MARVIN RH et al) June 10, 2010; entire document	1, 2, 3/1, 3/2, 4/3/1, 4/3/2, 5/1, 5/2, 16, 17, 18/16, 18/17, 19/18/16, 19/18/17, 78, 79, 80, 81/78-81/80

INTERNATIONAL SEARCH REPORT

International application No. .

PCT/US 15/27874

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 6-15, 20-30, 34-41, 43, 47-54, 56, 61-66, 70-76
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-"-Please See Supplemental Page-"*-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
Group I: claims 1-2, 3/1, 3/2, 4/3/1, 4/3/2, 5/1, 5/2, 16-17, 18/16, 18/17, 19/18/16, 19/18/17, 78-80, 81/78, 81/79, 81/80

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US 15/27874

-----Continued from Box No. III: Observations where unity of invention is lacking-----

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: claims 1-2, 3/1, 3/2, 4/31, 4/32, 5/1, 5/2, 16-17, 18/16, 18/17, 19/18/16, 19/18/17, 78-80, 81/78, 81/79, 81/80 are directed toward a wind turbine characterized in that the tower is supported by guy wires above the rotor line and the wind rotor is tilted to vertical.

Group II: claims 31-32, 33/31, 33/32, 42/33/31, 42/33/32, 44-45, 46/44, 46/45, 55/46/44, 55/46/45, 57-59, 60/57, 60/58, 60/59, 67-68, 69/67, 69/68, 77 are directed toward a wind turbine comprising: a rotating hub and a ring, external to the hub, coaxial to the wind rotor.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons.

The special technical features of Group I include a nacelle on top of the tower, the nacelle being capable of rotating at least 360 degrees in horizontal plane; a wind rotor of axial flow type, coupled to the nacelle; characterized in that the tower is supported by guy wires above the rotor line and the wind rotor is tilted to vertical in such a way that the tower's centerline crosses said rotation plane above the tower to avoid hitting the guy wires (which is not present in Group II).

The special technical features of Group II include an assembly, installable on top of the tower, the assembly comprising: a base, capable of horizontal rotation on the tower; an axial flow wind rotor, comprising: a rotating hub; a plurality of airfoil blades, coupled to the hub; each blade is supported by at least one external cable; a ring, external to the hub, coaxial to the wind rotor; at least one drivetrain assembly, comprising: an electrical generator with an electric rotor and a stator; a rotational element, engaging the ring and rotationally coupled to the rotor of the electrical generator for power take off from the ring from either mid-rotor or rotor periphery (which is not present in Group I).

The common technical features of Groups I-II include a wind turbine, comprising a tower and a wind rotor of axial flow type,

These common technical features are disclosed by US 2010/0143138 A1 (MARVIN): a wind turbine, comprising a tower and a wind rotor of axial flow type (see Marvin, abstract; claim 9).

Because the common technical features are disclosed by MARVIN, the inventions are not so linked as to form a single general inventive concept. Therefore, Groups I-II lack unity.