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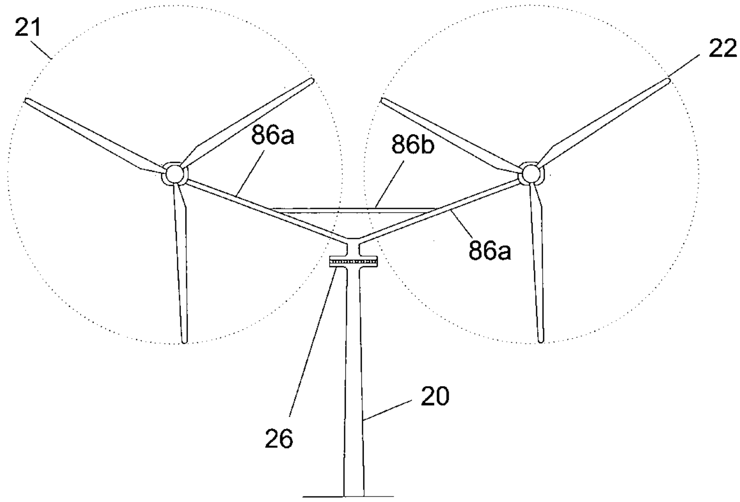

FIGURE 6

(57) Abstract: A wind turbine is proposed employing multiple horizontal axis rotors mounted on a single tower symmetrically on both sides of the tower. Said rotor units can share appropriate controls, support structures, and optionally some other operating components such as the generator or the gearbox, in order to provide a highly cost-effective turbine system. The control system for the multi-rotor system can control not only the yaw and the pitch, as in conventional single-rotor systems, but also the tilt angle of the rotors, adding a previously not available control parameter that can significantly increase operating efficiency in the presence of winds that are not perfectly horizontal, which is a common occurrence. The resulting system can provide substantially higher energy generation at lower investment costs and lower cost per KW generated.

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WIND ENERGY DEVICE

DESCRIPTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/208,750, filed February 28, 2009, which is hereby incorporated by reference and made a part hereof.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable.

TECHNICAL FIELD

[0003] The subject invention is related to the industry of alternative energy production and more specifically the industry of wind turbines for electricity generation.

BACKGROUND OF THE INVENTION

[0004] Wind turbines are well known mechanical devices used for hundreds of years to perform various mechanical works. The application and use of wind turbines to generate electricity was a natural and obvious application of turbines as soon the need for and availability of electricity uses was developed. Since the initial uses of turbines for generating electric power first appeared, many improvements and efficiencies have been applied to turbine technology.

[0005] Traditional turbines have at least one rotor blade mounted on a hub rotating about a horizontal axis. The turbine unit is usually fixed to the top of a tower structure and is capable of being rotated about the axis of the tower (yaw) in order to align with the direction of the wind. Most modern wind turbines of the current state of the art employ three rotor blades.

[0006] The ever increasing need for energy, combined with environmental concerns for alternative energy systems, provides the catalyst for more development and investment in wind power technology than ever before in the history of wind turbines.

[0007] Development trends in wind energy technology include off-shore installations, some of which are floating, while others are setting on the ocean floor. Other wind technologies include installing the turbines into kites, gliders, blimps, and/or other systems operating at altitudes above the earth while being tethered to the ground.

[0008] Wind energy technology is very important because it is environmentally clean and in virtually unlimited supply. Harnessing the wind for power consumption is a multi-billion dollar industry and the trends suggest and represent that a larger portion of the total power produced each year is produced from wind systems than the previous year. It is projected by some that this increasing production rate will last for many years to come. At the present time only a small percent of the total power generated comes from renewable alternative sources such as wind power generating systems.

[0009] Demands for wind generated power have lead to many governments of countries and states to put legislative policies in place regarding renewable power generation such as wind power. There are many countries that want to increase renewable energy generation from 5% of the total power produced to 10%, 20 % or even more. Scotland has announced plans for 50% energy from wind. The USA is considering a 20% minimum energy production from alternative energy. As a result, there is massive demand worldwide for wind turbines. Turbine manufacturers cannot meet the demand for turbine units. Many new turbine unit orders are booked years in advance and/or backlogged.

[0010] One possible solution to meet the demand would be to design and manufacture a wind turbine that can provide more power than current turbines, which usually reach only about 3 to 5 MW capacity. This invention makes that possible.

[0011] Another issue is the still relatively high cost of electricity generated from wind. There is increasing global pressure to reduce the cost of power and reach grid parity (match the cost of fossil fuel based energy). Alternative energy remains more expensive to produce than fossil fuel based systems. The present invention makes a major contribution in that area too.

[0012] Finally, another important issue regarding wind energy is the fact that many areas of the world are effectively running out of space for turbine installations. This is especially true in many European countries, with the best wind locations already taken. There is a real and present need to replace many existing aging turbines with new machines that can provide more power, and that can provide that power more efficiently than previous installations. With installation space at a premium and the high cost of leasing or buying space for turbines, a more space-effective solution is needed. The present invention makes a major contribution in that regard.

SUMMARY OF THE INVENTION

[0013] In order to get more power and reduce cost per KW, the wind industry has been trying to grow the size of rotors. It is well known that the amount of power generating capability increases with rotor diameter. Therefore, turbine technology and manufacturing companies continue to push the limits of rotor diameter. Turbine units have been manufactured with rotor diameters over 120 meters. However, many problems are also introduced as rotor diameter increases.

[0014] One problem is that the forces acting on the blades become overwhelming. These stresses can cause premature rotor failure and/or place enormous demands of the materials used in construction of the rotors. The engineering challenges that must be overcome increase exponentially with rotor size also, and the solutions lead to very high costs.

[0015] Another problem with increasingly larger rotors is that the large rotor size, towers, and the nacelle become so large that the cost of transportation becomes extremely high.

[0016] Yet another problem is that the exceptionally large rotor blades are becoming prohibitively expensive to manufacture. Many manufacturers are faced with the need to build super-sized manufacturing facilities just to manufacture the super-sized equipment. The subject invention addresses this problem by utilizing smaller diameter equipment which is more cost effective to manufacture.

[0017] Yet another problem with larger rotor diameters is that the cut-in wind speed becomes significantly increased. Therefore, the force required to initiate rotation of the rotors is such that low wind speeds may not be enough to get the turbine unit moving. The subject invention addresses this problem by making it possible to utilize smaller diameter turbine units in areas with lower wind speed, which require less wind speed to start rotation.

[0018] Still another problem with large wind turbines is the poor eye appeal or detraction to natural landscapes that wind farms impose. There is growing favor from public opinion to promote wind turbines, however, most people that favor them do not favor them being installed near them. The subject invention also addresses the eye appeal issue of wind turbines by providing some inherent design opportunities to artistically enhance the design and appearance of the turbine unit which are not available with the current state of the art turbines.

[0019] Further growth in rotor diameters is very problematic, and yet more efficient power generation technology is needed. Increased rotor size alone is not the solution. Rotor size does matter, but it must be in balance with how the rotor is utilized.

[0020] The subject invention addresses this problem by allowing efficient use of multiple rotors in each turbine unit to generate a multiple of the energy production of a single larger turbine unit. The multi-turbine unit of the subject invention at least doubles the power of the turbine installation without doubling the cost and without any increase in space requirements.

[0021] The subject invention proposes at least two or three turbines (or possibly more) arranged on the same tower structure. In one preferred embodiment, the turbine units can be operated independently of each other, or in another environment, they can share the use of some subsystems or components.

[0022] Another key innovative feature of this invention is the ability to tilt the rotors when the wind is not perfectly horizontal. Modern wind turbines are conventionally equipped with a yaw mechanism that allows the nacelle to turn around a vertical axis in order to orient themselves advantageously against the wind. However, they have no way to adjust their position around a horizontal axis, which is what is required for best orientation with respect to an ascending or descending wind, which is a common occurrence. Current turbines lack adjustability to this key parameter – in other words, a key needed knob is missing to adjust to this additional degree of freedom of the wind. As a result, current wind turbines operate under suboptimal conditions in ascending or descending winds.

[0023] The reason modern turbines lack a tilting mechanism is because the tilting movement in a conventional turbine would cause the rotor blades to clash with the tower mast when tilted down to adjust the turbine to ascending winds. The subject invention provides a mechanism where this problem is eliminated and a tilting mechanism can be used without any danger of such a clash, leading to a substantial increase in operating efficiency.

[0024] Other advantages and features of the subject invention will be apparent to those skilled in the art.

[0025] One advantage of the subject invention is the cost reduction from sharing some subsystems, such as the same yawing system, the same tower (reinforced, therefore not really the same tower, but still more cost-effective than multiple towers), the same space (cost of the leased or bought land is shared), the same transformers, the same connection to the grid, the same maintenance, the same communications equipment such as phone line and diagnosis equipment, and potentially others.

[0026] Another advantage of the subject invention is that the multi-turbine unit provides a system in which each turbine includes its own nacelle and therefore each turbine works independently. This configuration provides a measure of redundancy in case of failure.

[0027] Another advantage of the subject invention is that the multi-turbine unit can provides a combination of two smaller rotors that can produce the same or more electric power than a larger single rotor, but with a lower cut-in wind speed and therefore longer periods of time in operation. The net result is more continuous hours of energy production each year.

[0028] Another advantage of the subject invention is that the multi-turbine unit provides one additional degree of freedom to optimize power generation (angle of rotor relative to tower). This advantage provides a major advantage in power generation. Wind streams are typically not perfectly horizontal, and often are at a substantial degree from a horizontal line. The advantage of the subject invention to tilt upward and downward to better confront the wind stream is a major advantage in efficient use of the turbine. The consequence is better operating efficiency and higher power generation.

[0029] Another advantage of the subject invention is that the multi-turbine unit can provide a combination of two smaller rotors that can be less expensive than a larger single rotor, reducing cost per KW.

[0030] Another advantage of the subject invention is that the multi-turbine unit with smaller rotors required can reduce transportation and still generate the same or more electricity than a larger rotor.

[0031] Another advantage of the subject invention is that the multi-turbine unit can have better aerodynamic performance because of a support structure which introduces less air pressure resistance to the sweep of the rotor blades as they pass in proximity to the support structure, eventually resulting in longer blade durability and better turbine longevity.

[0032] Another advantage of the subject invention is that the multi-turbine unit provides a means to dramatically increase total energy capacity production in a wind farm. This advantage is accomplished by taking advantage of the dense population that smaller rotor turbines are permitted in a given area compared to the population density of large rotor turbines in the same geographical wind farm area. The impact of this is more energy at lower cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] To understand the present invention, it will now be described by way of example, with reference to the accompanying drawings in which:

[0034] Figure 1 is a front view of a conventional prior art turbine;

[0035] Figure 2 is a side view of the turbine of Figure 1;

[0036] Figure 3 is a partial blown up view of the turbine of Figure 1;

[0037] Figure 4 is a front view of one embodiment of the invention;

[0038] Figure 5 is a front view of another embodiment of the invention;

[0039] Figure 6 is a front view of another embodiment of the invention;

[0040] Figure 7 is a perspective view of the embodiment of Figure 6;

[0041] Figure 8 is a front view of an embodiment showing one turbine rotation;

[0042] Figure 9 is a front view of an embodiment showing another turbine rotation;

[0043] Figure 10 is a front view of another embodiment of the invention;

[0044] Figure 11 is a schematic view of a turbine drive system;

[0045] Figure 12 is a schematic view of another turbine drive system;

[0046] Figure 13 is a schematic view of another turbine drive system;

[0047] Figure 14 is a schematic view of another turbine drive system;

[0048] Figure 15 is a front view of another embodiment of the invention with three turbines;

[0049] Figure 16 is a front view of another embodiment of the invention, such as an offshore embodiment;

[0050] Figure 17 is a front view of another embodiment of the invention;

[0051] Figure 18 is a side view of the embodiment of Figure 17;

[0052] Figure 19 is a top view of the embodiment of Figure 17;

[0053] Figure 20 is a front view of a prior art turbine;

[0054] Figure 21 is a front view of another embodiment of the invention;

[0055] Figure 22 is a front view of another embodiment of the invention;

[0056] Figure 23 is a front view of another embodiment of the invention;

[0057] Figure 24 is a front view of the embodiment of Figure 22;

[0058] Figure 25 is a front view of another embodiment of the invention;

[0059] Figure 26 is a front view of another embodiment of the invention;

[0060] Figure 27 is a front view of another embodiment of the invention;

[0061] Figure 28 is a front view of the embodiment of Figure 26;

[0062] Figure 29 is a front view of the embodiment of Figure 27;

[0063] Figure 30 is a side view of an installation of a turbine; and,

[0064] Figure 31 is a side view of an installation of a turbine with the turbine tiled down.

DETAILED DESCRIPTION

[0065] **Figure 1** shows a front view of a conventional prior art turbine. Generically, **10** is a schematic representation of the sweep area of the three rotor blades **12, 13 and14,** which are arrayed around hub **16**. The nacelle **15** is the machine house, which contains the hub, gearbox, generator, yaw motor, anemometer, mechanical brake, main drive shaft, yaw bearing, controller, wind vane, rotor hub, rotor blade pitch mechanism, and other components, all mounted on tower mast **11**.

[0066] Modern turbines work when the rotor blades respond to passing wind streams causing the turbine to rotate. The blades can be rotated around their longitudinal axis using a blade pitch mechanism located in the hub to optimize their angle with respect to the wind.

[0067] The entire nacelle and rotor is turned to face into the wind to further take advantage of wind speed using a yaw mechanism. The yaw mechanism usually includes a system of gears and electric motors (the so called yaw or azimuth motors) which cause the nacelle to rotate around the tower. A controller monitors the wind direction and a host of other parameters and initiates the yaw mechanism as needed to keep the rotor facing into the wind.

[0068] As the rotor blades sweep through the air, they turn a central shaft in the nacelle which is connected to a gear box. The gear box is connected to the generator to produce electric power. A shaft between the generator and the gear box includes a brake mechanism which is used to stop the rotor from turning and/or to slow it down to maintain a certain speed.

[0069] The controller monitors wind speed and wind direction and makes adjustments to the two basic mechanisms it has to control turbine operation: a) the pitch of the blades, and b) the yaw. In the future through this invention there will be a third key mechanism: the tilt mechanism, which is not available today.

[0070] **Figure 2** shows a side view of the same conventional prior art as shown in **Figure 1**.

[0071] **Figure 3** shows the nacelle **15** or machine house with a schematic representation of its internal components. Rotor blades **14** sweep through the air connected at the root of the blade at the hub **16**. The rotational motion turns the slow shaft **84** in the nacelle which is connected to gear box **17**. Gear box **17** is connected to generator **18** by fast shaft **85** to produce electric power. Some types of generators, typically called direct-drive generators, eliminate the need for a gea box. In such a case (not shown in this Figure) the slow shaft would connect directly with the direct-drive generator.

[0072] **Figure 4** shows a first embodiment of the subject invention. Turbines **21** and **22** are mounted on the same tower **20**. Truss **23** is depicted as a bridge type schematic structure, which is a structure that supports both of the turbines, basically a beam, or a system of beams. It can be a lattice or round structure, or rectangular beams, etc. **24** and **25** are the bridge supports, which are also beams, tubes or other brace type structures designed to rigidly support the bridge. Other embodiments of the subject invention are described herein which do not employ brace systems as depicted in **Figure 4**.

[0073] In this embodiment, the two turbines **21** and **22** are basically independent from each other in their operation. They can rotate at different speeds from each other depending on the wind they are exposed to. Independently operating nacelles **27** and **28** contain all the typical subsystems and components, such as transmission and generator. Variations on the theme provide nacelles **27** and **28** to be direct-drive turbines, with only a generator and no transmission, in which case the nacelles only contain the hub, the slow shaft, the generator and the pitching mechanism for the turbine blades.

[0074] Turbines **21** and **22** are at substantially the same vertical height from the installation surface, so they can both benefit from maximum altitude and wind strength. A symmetrical design with equal hub height and equal distances from the turbine units to the tower is preferred, to avoid imbalances that would be otherwise created due to the wind gradient. If the turbines are mounted at different altitudes the vertical wind gradient would cause an imbalance by exerting different thrust on each side of the tower and therefore applying a net torque around tower **20**. The balanced symmetrical concept of this invention avoids imbalances and therefore minimizes cost for tower **20**, while simultaneously protecting all subsystems and components from excessive stresses that would result from imbalanced forces.

[0075] Also on **Figure 4**, tower **20** has two subsections, which are rotateable at joint **26** relative to each other. Joint **26** is equipped with a motorized yawing system with one or more azimuth drives (typically electric motors) which rotate the top subsection of the tower with respect to the bottom subsection to orient the turbine rotors in the optimal direction with respect to the wind.

[0076] **Figure 5** shows another embodiment of the subject invention depicting a T-structure with horizontal bridge **23**. Those skilled in the art will appreciate that bridge **23** may be heavier in construction than bridge **23** depicted in **Figure 4** because of the lack of bridge supports **24**. However, this type of turbine support structure offers improved aesthetic appearance against the landscape. This type of structure is also favorable to birds flying near the turbine because there are fewer obstacles to navigate.

[0077] **Figure 6** shows another embodiment of the subject invention depicting a V-structure with upward oriented braces **86a** and **86b**. Those skilled in the art will appreciate that braces **86a** may be heavier in construction than bridge **23** depicted in **Figure 4** because of the lack of bridge supports similar to **24**. However, this type of turbine support structure offers improved aesthetic appearance against the landscape. This type of structure is also favorable to birds flying near the turbine because there are fewer obstacles to navigate.

[0078] **Figure 7** is a 3D view of the embodiment shown in **Figure 6a**.

[0079] **Figures 8 and 9** show that in a dual configuration, the turbines can be made to rotate in the same or opposite directions depending on the types of turbine rotors used. Clockwise rotation is the unofficial standard as shown in **Figure 8**, while **Figure 9** depicts one rotor with clockwise rotation and one rotor with counterclockwise rotation. Rotors with the same direction of rotation may be more acceptable in the landscape and people may perceive them as more acceptable, because they are more familiar with them and used to seeing turbines rotate all in the same direction. Counter-rotating rotors may have aerodynamic advantages, because they may focus the air flow on the dual turbines, increasing torque and thereby energy production.

[0080] **Figure 9** shows an embodiment of the subject invention with 3 rotors mounted on top of tower **20**. Those skilled in the art will appreciate this depiction is simply a schematic and that the support and brace system required for this embodiment will obviously include complex structural enhancements not depicted in detail. The rotateable joint **26** and the yawing mechanism have been moved down closer to the ground surface to accommodate the bridge supports.

[0081] **Figure 10** is another embodiment of the subject invention depicting two rotors **21** and **22**. This embodiment achieves an improvement in cost reduction by sharing subsystems and components. Instead of separate nacelles as in the previous Figures, **Figure 9** has a central nacelle **30**. The central nacelle **30** allows the sharing of one or more of the components such as the transmission, generator and other subsystems and components.

[0082] **Figure 11** shows how some subsystems and components can be shared between the 2 rotors in the embodiment with a central nacelle. **40** and **41** are the rotors, which in this figure are assumed to be rotating in the same direction. The left rotor **40** drives bevel gear **45**, which engages with bevel pinion **42**, which drives shaft **43**. Shaft **43** transmits the power to the central nacelle **44**, which contains all the typical subsystems and components, such as a transmission and a generator (or in the case of direct-drive turbines, only a generator and no transmission). In the nacelle **44**, the mechanical energy from shaft **43** converted it into electrical energy. The same process happens on the right side of **Figure 10**. Notice that because of the way the gears are connected with each other, shaft **43** and shaft **46** rotate in opposite directions. That may be desirable or undesirable depending on the type of transmission and generator being used. If the same direction of rotation is desired, the gear arrangement shown in **Figure 12** can be used.

[0083] **Figure12** is very similar to **Figure 10**. The basic difference is that the shafts entering the central nacelle **54** have the same direction of rotation. **50** and **51** are the rotors, which in this figure are assumed to be rotating in the same direction. The left rotor drives bevel gear **55**, which engages with bevel pinion **52**, which drives shaft **53**. Shaft **53** transmits the power to the central nacelle **54**, which contains all the typical subsystems and components, such as a transmission and a generator (or in the case of direct-drive turbines, only a generator and no transmission). In the nacelle **54** the mechanical energy from shaft **53** is converted into electrical energy. The same process happens on the right side of **Figure 11**.

Notice that because of the way the gears are connected with each other, now shaft **53** and shaft **56** rotate in the same direction.

[0084] The configurations shown in **Figures 11** and **12** can be used with rotors that rotate in the same direction or with rotors that rotate in the opposite direction.

[0085] A potential problem of **Figures 11** and **11** is that shafts **43** and **53** are low speed shafts and must carry the full torque generated by their respective wind rotors, which is very high. That makes those shafts very heavy and expensive.

[0086] **Figure 13** shows an alternative embodiment of the subject invention. The transmissions **65** and **61** are directly attached to the wind rotor shafts (instead of being located in the central nacelle as in **Figures 10** and **11**). Therefore the torque is greatly reduced before reaching the shafts **63** and **65**. This configuration allows a more cost-effective design of the driveline leading from the wind rotors to the generator in the central nacelle.

[0087] **Figure 14** is a similar embodiment to the ones previously shown, but it adds clutches **66** and **67**, which allow a lower wind cut-in speed by allowing the wind rotors to start rotating at very low wind speed with the rotors basically disengaged from the load (the transmission and generator). The load is applied only after the rotors have acquired some speed and kinetic energy.

[0088] **Figure 15** shows an embodiment with three turbines.

[0089] **Figure 16** is another embodiment showing an off-shore version of the turbine of the subject invention. The schematic depiction shows an installation embedded in the ocean floor. Those skilled in the art will easily appreciate that the features and advantages of the subject invention can be incorporated regardless of which particular foundation structure is utilized for the off-shore installation, such as anchored to the ocean or lake ground, floating or other methods. A platform is depicted for access and maintenance. The wavy line represents water level.

[0090] **Figures 17, 18** and **19** depict an embodiment of the subject invention with two turbines **27** and **28** mounted on tower **20** shown in a front view, top side view, and top view respectively. Brace supports **25** in **Figures 18** and **19** are hidden behind brace supports **24** and out of view in **Figure 17**. Similarly, brace support **66b** shown in **Figure 18** is hidden behind brace support **66a** shown in **Figure 17.** These brace supports or similar supporting structures may be required in certain support designs, and are placed so that they pose no additional interference to the wind stream passing through the rotor sweep area.

[0091] **Figures 18** and **19** introduce another embodiment schematically shown as support component **82a** supporting moveable counter weight **82b.** This moveable counter weight feature can be employed to help stabilize the individual turbine to offset the forces imposed upon it by the wind stream. This counter weight system is able to be adjusted by moving the counter weight **82b** along support member **82a** to establish a more stable turbine.

[0092] **Figure 20** depicts a common prior art turbine while **Figure 21** depicts an embodiment of the subject invention featuring two turbines. **Figure 20** has a relatively large diameter rotor while **Figure 21** features two turbines with a relatively smaller rotor diameter. The two rotors in **Figure 21** are sized such that they are capable of generating as much or more power than the single large rotor in **Figure 20**.

[0093] A comparison between Figures 20 and 21 reveals that the new invention in Figure 21 has aerodynamic advantages, because it reduces the obstacles to wind flow located behind the turbine, which cause power losses and create fatigue effects on the blades. Tower **76** has a relatively thick cross section **75** compared to cross sections **70a** and **70b.** Those skilled in the art will readily appreciate that the relative thickness of the structure required for a relatively large turbine will obviously require more structural thickness than is required for a relatively smaller turbine – other things being equal.

[0094] **Figures 20** and **21** also allow some comparative observations to be made between the large turbine and the smaller multiple turbines. Those skilled in the art will readily appreciate that the larger turbine requires a larger manufacturing facility to produce the rotors than is required for the smaller turbines. Similarly, the transportation cost of the larger rotors will naturally be more costly than the smaller rotors. Those skilled in the art will appreciate that the shear mass of the larger rotors will require more force to initiate rotation than smaller rotors, and as a result, the minimum wind speed required to maintain rotation will be greater for the large rotor than for the smaller rotors.

[0095] Those skilled in the art will also appreciate that when the large rotor is under maintenance the entire turbine unit does not produce power, however, in the smaller multiple rotor design of the subject invention, one turbine can be halted for maintenance while the other turbine continues power generation. Therefore, the total up-time and total power generated by the smaller multiple rotors is capable of producing more than the equivalent power of the larger rotor. Therefore, the subject invention provides a means of scaling for reduced power generation that is impossible with a single and/or larger turbine.

[0096] **Figures 22** and **23** depict an embodiment of the subject invention with multiple rotors compared to a typical prior art rotor of the same relative rotor diameter. The shaded areas **73a** and **73b** represent the area of air pressure restriction that develops as the rotor blade sweeps past the proximity of the support structures with thickness **70a** and **70b** respectively. Similarly, shaded area **72** represents the area of air pressure restriction that develops in a typical prior art turbine as the rotor blade passes near proximity to the support structure with thickness **71**. It can easily be recognized that the stress effects of **73a** and **73b** will have less impact on the rotor blades than that of **72** due to the magnitude of the air pressure restriction difference. The greater the air pressure restriction the greater the stress imparted to the rotor blade.

[0097] **Figure 24** is the same multiple turbine embodiment shown in **Figure 22**. Assume that this multiple turbine embodiment has an energy production capacity of "X" kW. The turbine in **Figure 23** represents a large rotor turbine. Assume this larger turbine also has an energy production capacity of "X" kW. This is possible because the smaller diameter multiple rotors produce in tandem the equivalent energy capacity of the larger diameter single rotor.

[0098] The air pressure restriction area **77** that is generated by the rotor passing by the near proximity of thickness **75** is significantly more severe than areas **73a** and **73b.** Once again, it can easily be recognized that the stress effects of **73a** and **73b** will have significantly less impact on the rotor blades than that of **77** due to the magnitude of the air pressure restriction difference. The greater the air pressure restriction the greater the stress imparted to the rotor blade. This is especially problematic for larger diameter rotors.

[0099] **Figure 26** represents another embodiment of the subject invention of the multiple turbine system. The multiple turbines **21** and **22** give the designer many options to design the turbine in eye appealing ways not conceivable or possible with traditional turbines. An arc shaped sweep or some kind of semicircular structure **78a** or even an irregular shaped structure is possible to incorporate into the design of the multiple turbine embodiments. Those skilled in the art will appreciate the variations on the theme for dynamic and eye appealing esthetic turbine designs which are only limited by one's imagination.

[00100] **Figure 27** represents another embodiment in which support structure **78b** is predominantly in the shape of a circle or hoop like structure. Once again, it is obvious to those skilled in the art that alternative variations on the theme of esthetic and eye appealing structural turbine designs are possible with the multiple turbine embodiments of the subject invention.

[00101] **Figure 28** shows the embodiment of **Figure 26** and reveals that the air pressure restriction area that builds up between the rotor blades and the support structure builds gradually as shown by **80** and maxes out with area **79b.** This gentle build up of air pressure restriction is much less severe on the rotor blades than traditional turbines. The arc shaped support structure **78** does not have a substantial portion oriented along an axis that is in-line with the radius of the rotor. Traditional turbines have a support structure **76** as shown in **Figure 25** which is substantially in-line with the radius of the rotor. Therefore, the stresses built up and imparted to the rotor blades during each pass near the proximity of the support structure of the subject embodiment is significantly less than occurs in traditional turbines with support structures that are substantially in-line with the radius of the rotor.

[00102] **Figure 29** shows the embodiment of **Figure 27** and reveals that the air pressure restriction area that builds up between the rotor blades and the support structure builds gradually as shown by **80** increases as depicted by **79c** and maxes out with area **79b.** Once again, this gentle build up of air pressure restriction is much less severe on the rotor blades than traditional turbines. The circular shaped support structure **78** does not have a substantial portion oriented along an axis that is in-line with the radius of the rotor.

[00103] **Figure 30** shows a common installation arrangement of a turbine on top of a hill or other topographical elevation. The advantage of such a location is that the wind is

accelerated upstream, providing high velocity at the top of the topographical formation. A significant part of that advantage is lost though if the turbine does not confront the wind perpendicularly.

[00104] The main shaft in a typical turbine installation has a fixed angle with respect to the ground such that the axis of the main shaft is substantially parallel to the horizontal plane. Traditional turbines can not tilt downward to confront the wind in a perpendicular orientation because the rotors would come too close to the tower mast that they may actually contact the tower mast and self-destruct. As a result of this design problem, a tilting mechanism is not provided and a lower efficiency is accepted (until now).

[00105] The turbine depicted in **Figure 30** is a twin turbine embodiment of the subject invention. The turbine employs a tilting system that allows the multiple turbines to tilt upward and downward so as to confront the wind head on. There is danger of clash with the tower when downward tilting, because there is no tower mast in that area (the turbines are held in place by side supports).

[00106] **Figure 31** shows the twin turbine embodiment tilted downward without a clash with the tower. The tilting mechanism can be continuously monitored and controlled similar to methods utilized to control yaw.

CLAIMS

What is claimed is:

1. An electrical generation system to generate electricity from wind energy, comprising at least the following subsystems, in functional combination:

a tower to provide the necessary altitude for favorable wind velocities;

a carrier structure rotatably attached to the tower, substantially near to or at the top of the tower, said carrier structure providing lateral extensions to which at least two nacelles can be attached, symmetrically on each side of the tower;

a rotor for each nacelle, rotatable at each nacelle around a generally horizontal rotor axis of rotation and comprising one rotor hub and at least one rotor blade, said blade rotatably attached at or near its root to the rotor hub;

a generator and an optional transmission in each nacelle, to raise the rotational speed and then convert the rotational energy into electric energy;

a pitching mechanism in each rotor hub or in each nacelle that can rotate the blade about a blade axis of adjustment which is substantially longitudinal to the rotor blade, in order to adjust the blade's angular position relative to the prevailing wind conditions and desired operating conditions;

a yawing mechanism that can rotate the top section of the tower, along with the carrier structure and the at least two nacelles and the at least two rotors, around the bottom section of the tower, in order to simultaneously orient the at least two rotors in the desired direction, such as frontally against the wind for maximum power generation or at a different angle in the presence of extreme winds or to park the turbines for maintenance; and,

a tilting mechanism that can rotate the rotors and nacelles around the lateral extensions of the carrier structure in order to achieve the desired angle of attack of the wind when the wind direction is not perfectly horizontal, such as upward winds and downward winds, thus providing one more key degree of freedom in the adjustment of the turbines for maximum energy generation, which is a new degree of freedom not previously available.

2. System of claim 1, wherein the number of rotors is an even number and the hubs of the at least two rotors are substantially at the same height relative to the ground, in order to achieve a balanced situation with zero or very small net torque around the tower due to the symmetrical nature of the forces so generated.

3. System of claim 1, wherein the nacelles are fixedly attached to the carrier structure, without the ability to tilt around the lateral extensions of the carrier structure.

4. System of claim 1, wherein the tower includes a first bottom section attached to the ground and a second top section which is rotatably attached to the bottom section of the tower, so that the carrier structure can be fixedly attached to the top section of the tower, with the yaw movement being achieved through the rotation of the top section of the tower with respect to the bottom section of the tower.

5. System of claim 1, wherein the carrier structure is comprised of a truss type frame support cantilevered symmetrically outward on two sides so that two turbines are supported straddle of the tower mast.

6. System of claim 1, wherein the carrier structure is comprised of a bridge beam type frame support cantilevered symmetrically outward on two sides oriented in the general shape of a "T" relative to the tower mast, with or without additional connecting beams for additional strength, so that two turbines are supported straddle of the tower mast.

7. System of claim 1, wherein the carrier structure is comprised of a pair of beam type frame supports cantilevered symmetrically outward on two sides and oriented in the general shape of a "v" or an inverted "V" relative to the tower mast, with or without connecting beams between the sides of the "V" for additional strength, so that two turbines are supported straddle of the tower mast.

8. System of claim 1, wherein the carrier structure is comprised of an open truss type frame support cantilevered symmetrically outward on two sides so that two turbines are supported straddle of the tower mast, with the structure further including brace and truss support members extending rearward from the rotors so as to provide support against forces exerted by prevailing winds acting upon the turbine.

9. System of claim 1, wherein the at least two rotors share the use of at least one component, such as a common generator, a common transmission and/or other common elements.

10. System of claim 1, wherein an additional central nacelle is located at or near the center of the carrier structure between the lateral rotors.

11. System of claim 10 where the central nacelle does not have its own rotor and is just used to support the function of the lateral rotors.

12. System of claim 10 where the central nacelle is equipped with its own rotor and other needed components to operate.

13. System of claim 1, wherein the at least two rotors share at least one component, such as a generator, a transmission and/or other elements in the system through a system of shafts and gears.

14. System of claim 1, wherein the at least two rotors share at least one component, such as a generator, a transmission and/or other elements in the system through a system of belts or cables.

15. System of claim 13, wherein the at least one shared element is located substantially near the bottom of the tower, with a system of shafts and gears transferring power from the top of the tower to the bottom of the tower.

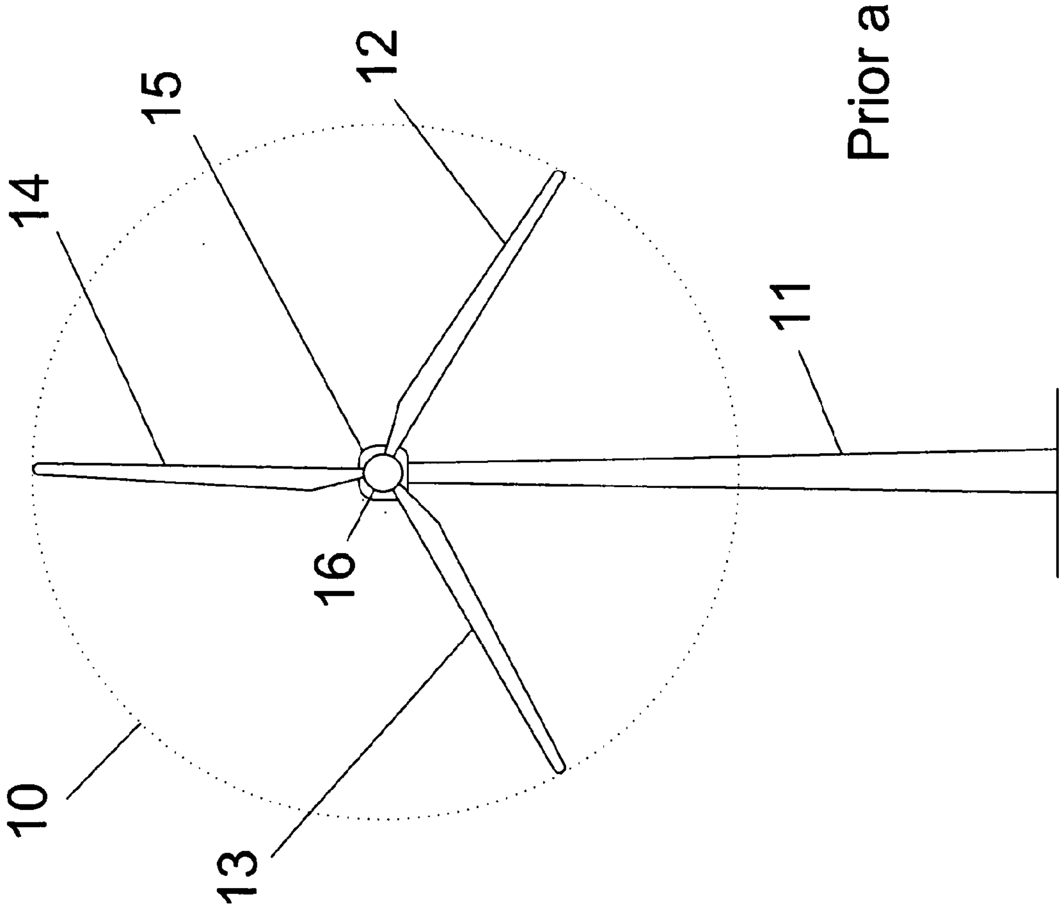
16. System of claim 14, wherein the at least one shared element is located substantially near the bottom of the tower, with a system of belts or cables transferring power from the top of the tower to the bottom of the tower.

17. System of claim 1, wherein the system is an off-shore application with multiple rotor units mounted straddle a tower mast, with said tower mast either resting on, inserted into or embedded in the floor of a body of water such as the ocean or a lake.

18. System of claim 27 wherein the off-shore system is not resting on the floor of a body of water, but instead on a floating body or structure, including a vessel or other structure supported primarily or partially by buoyancy.

19. System of claim 1, wherein multiple rotors are designed to rotate in the same direction.

20. System of claim 1, wherein multiple rotors are designed to rotate in opposite directions.



Prior art

FIGURE 1

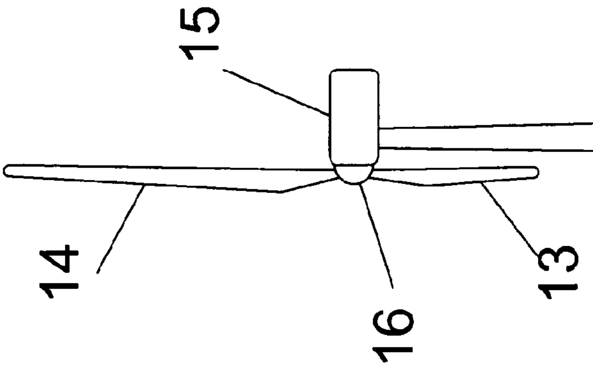
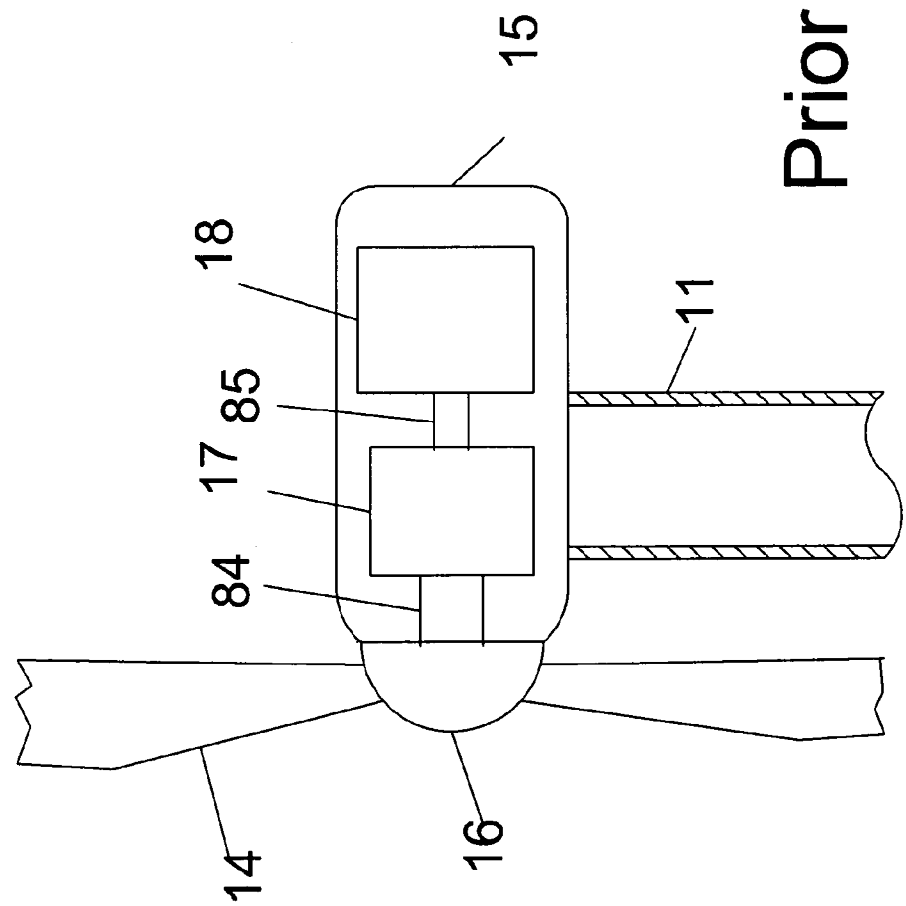


FIGURE 2



Prior art

FIGURE 3

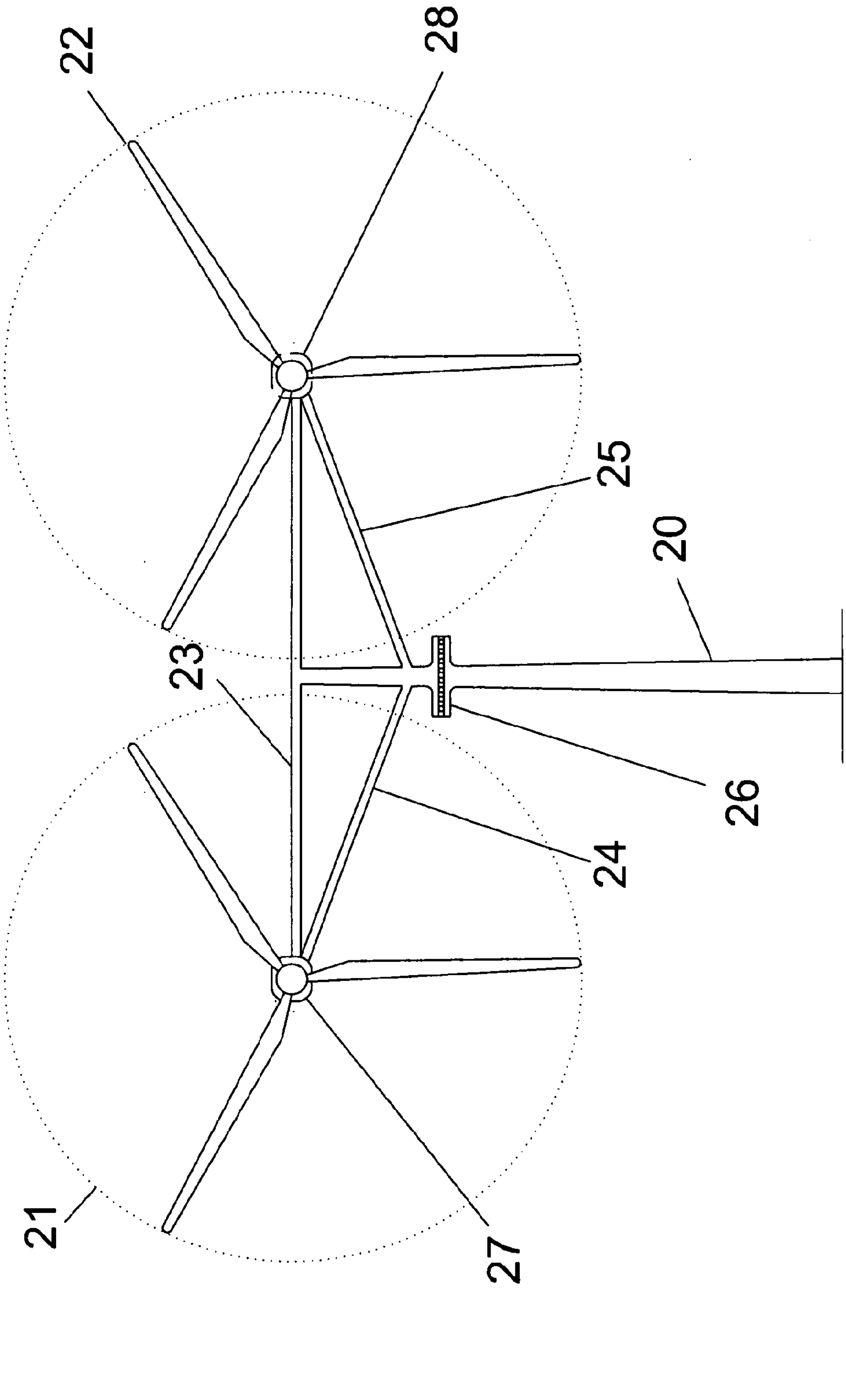


FIGURE 4

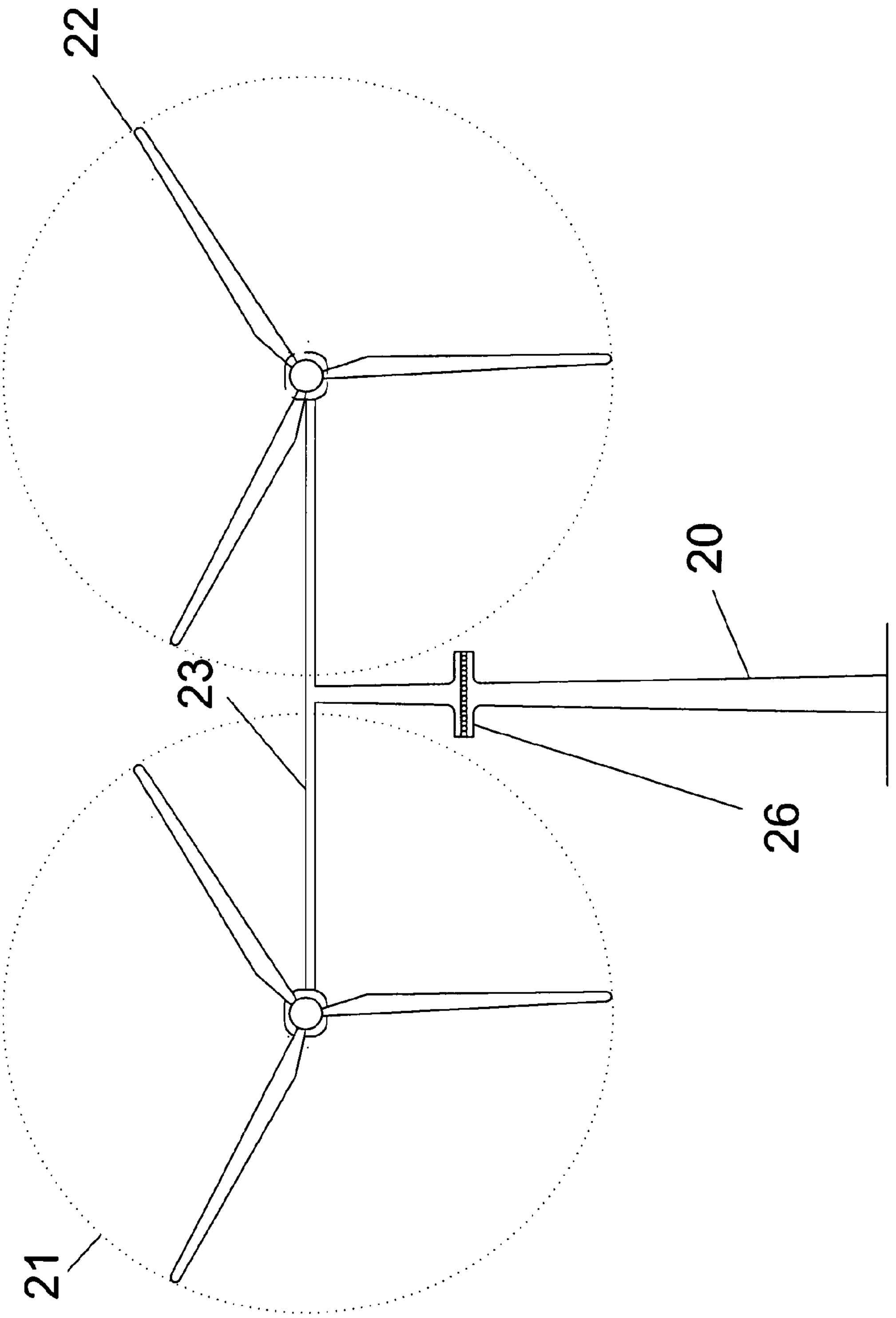


FIGURE 5

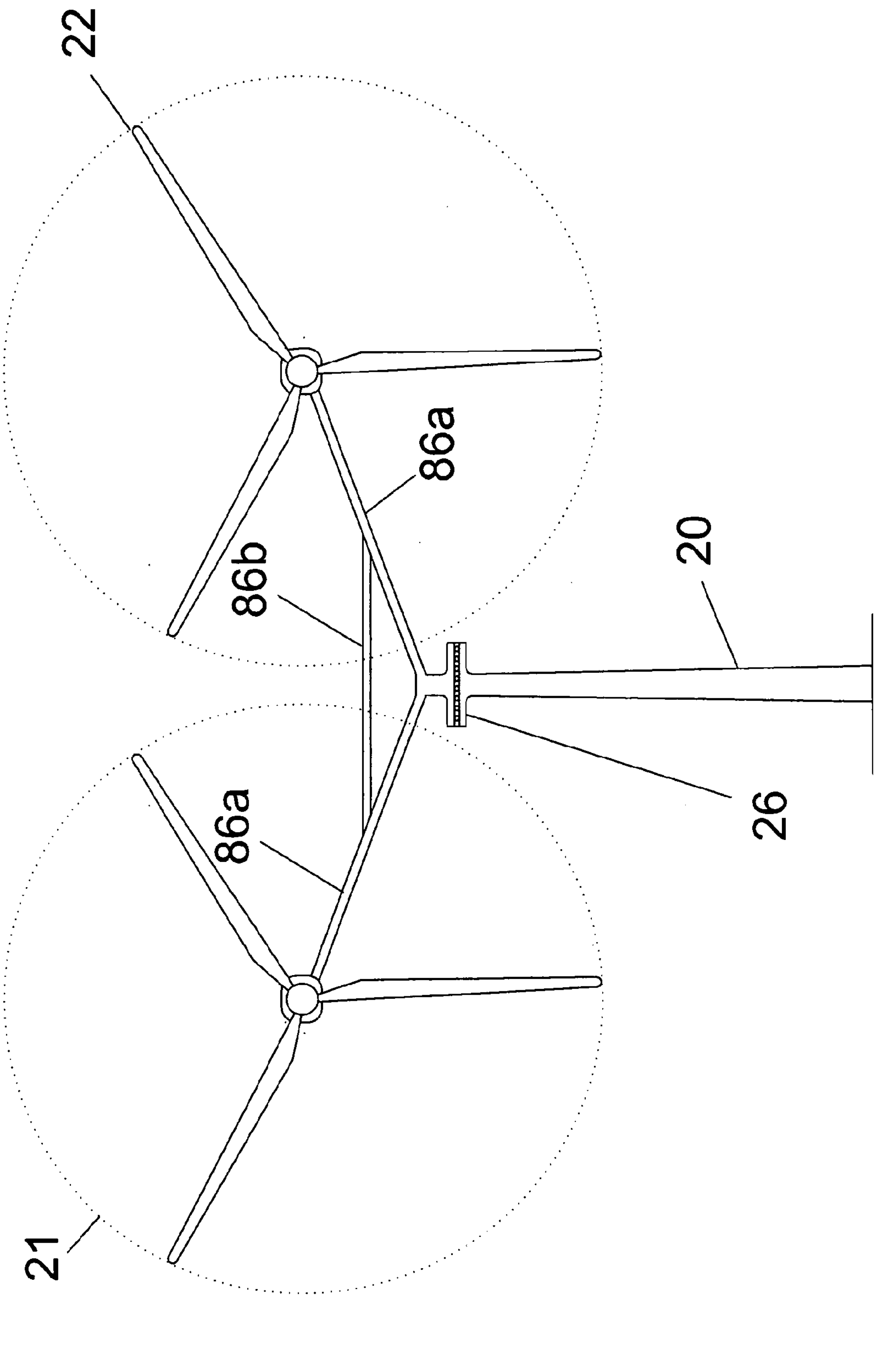


FIGURE 6

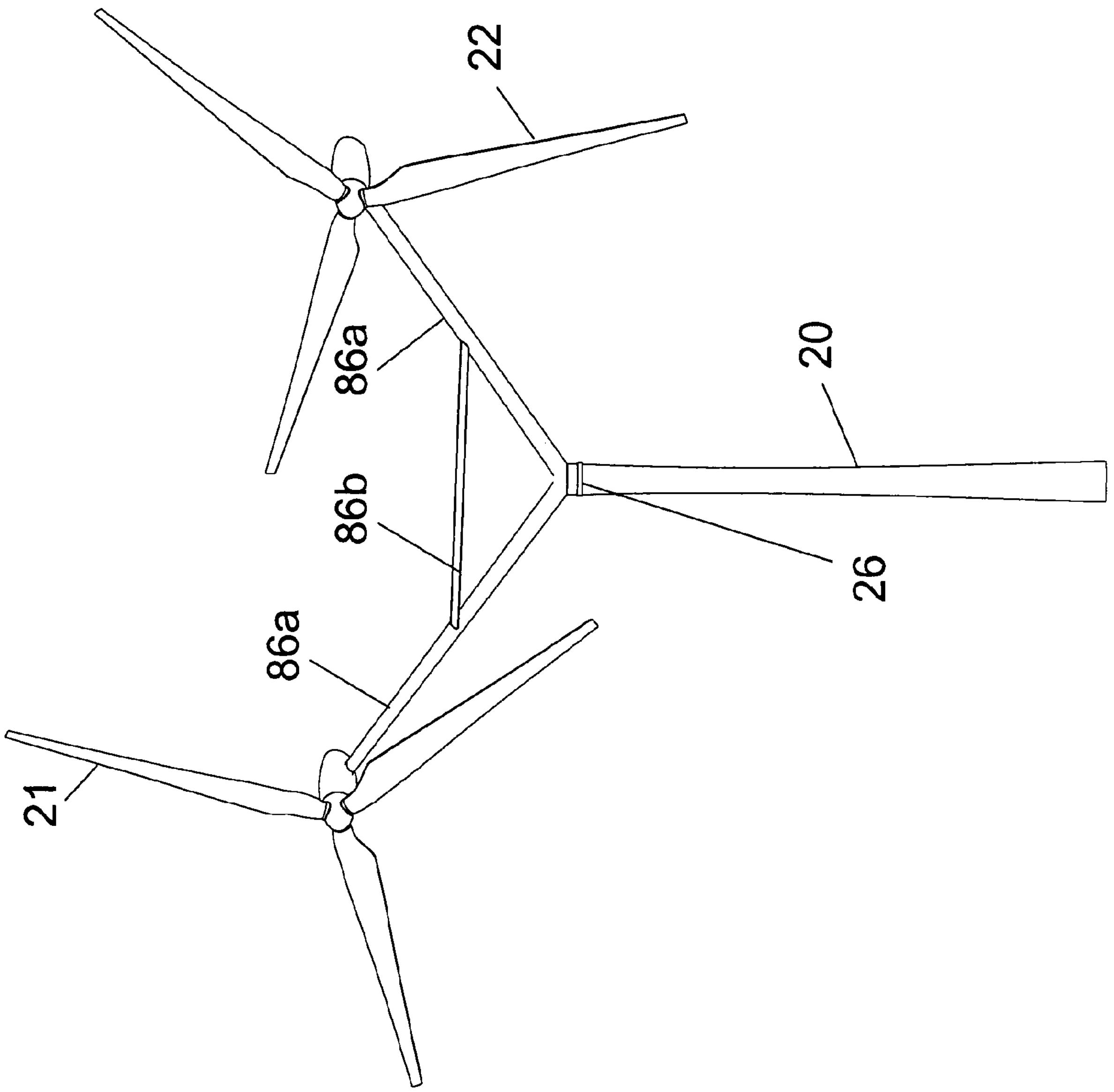


FIGURE 7

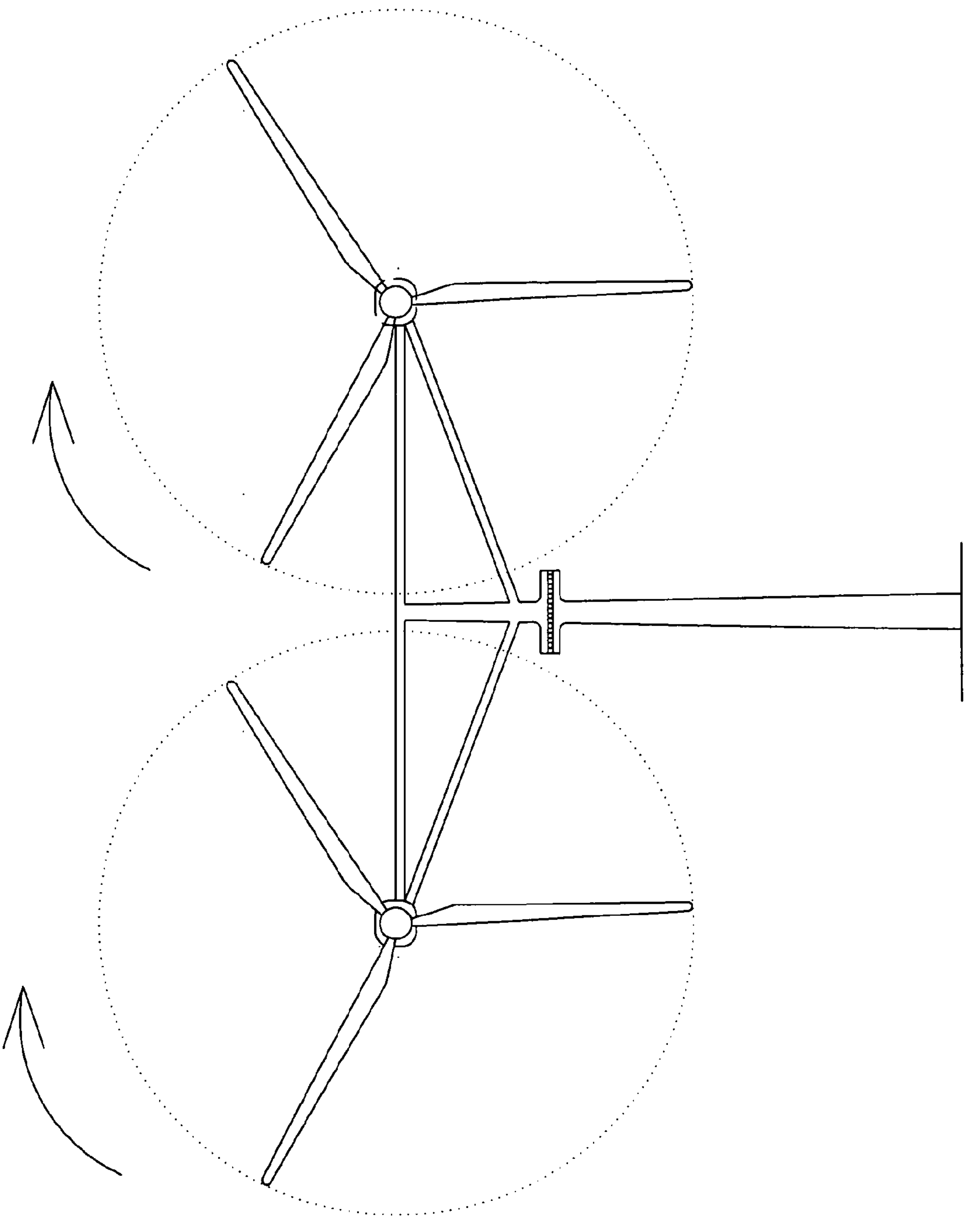


FIGURE 8

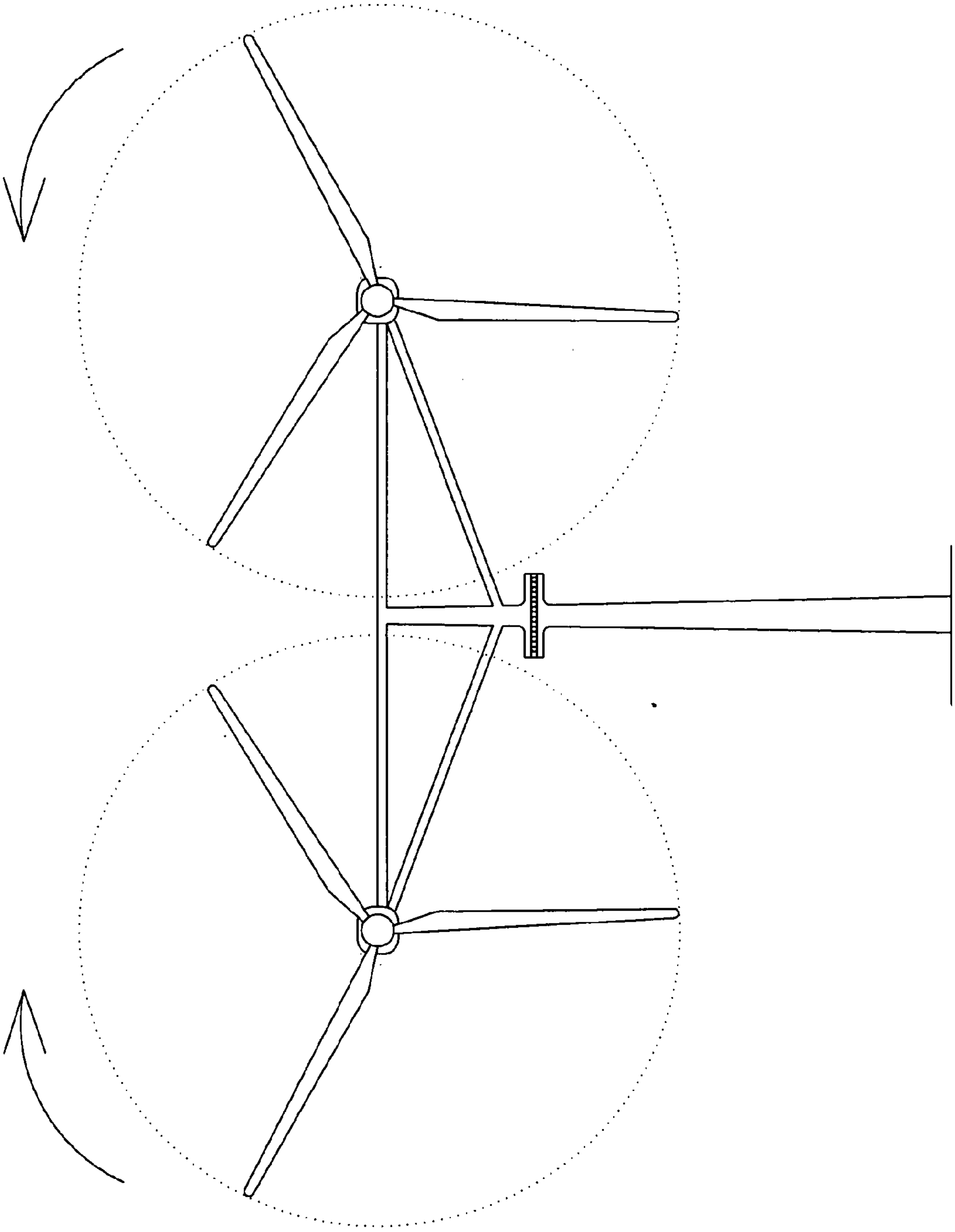


FIGURE 9

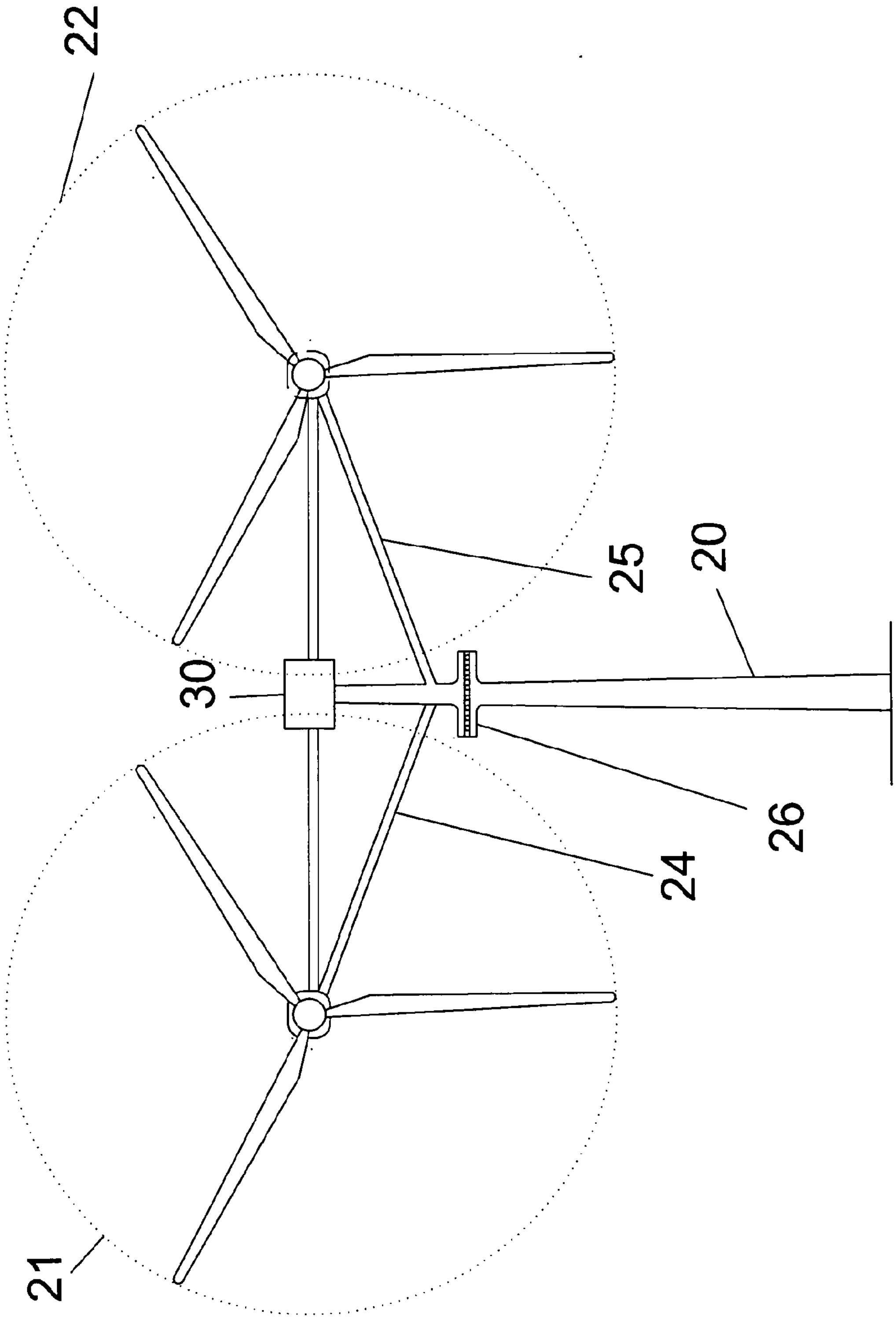


FIGURE 10

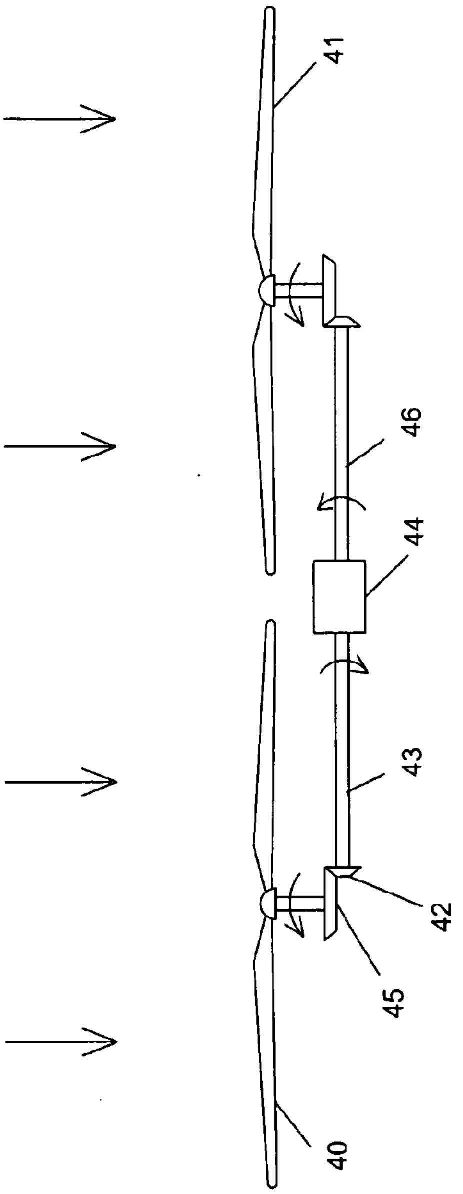


FIGURE 11

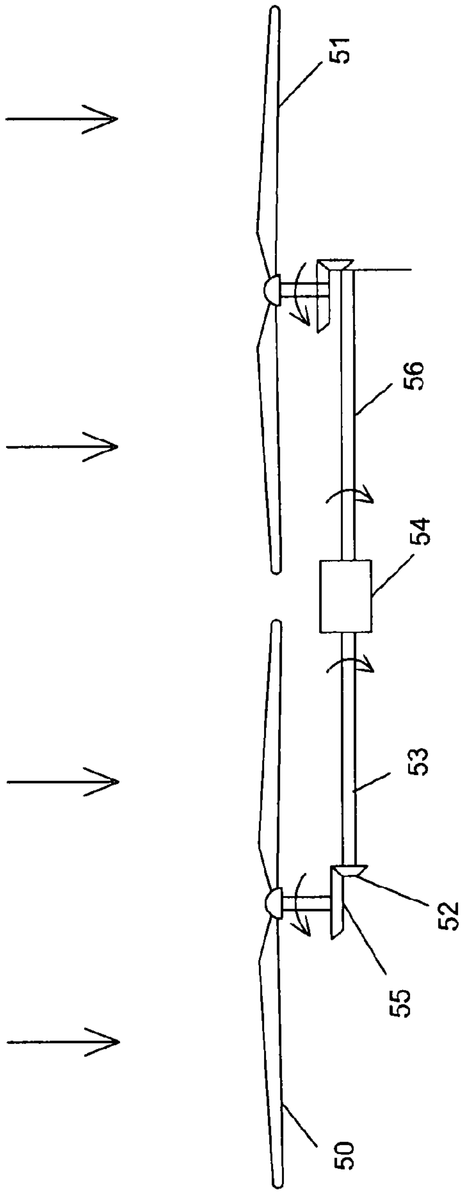


FIGURE 12

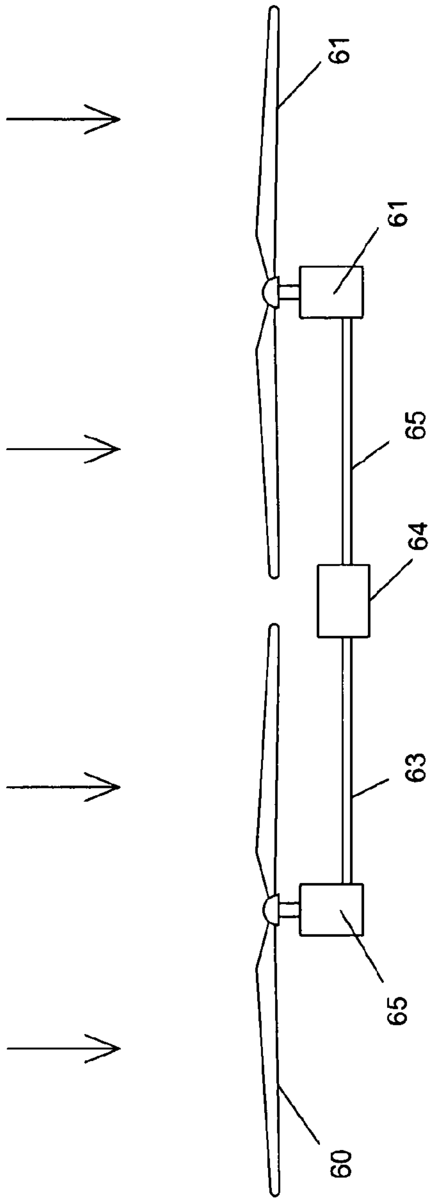


FIGURE 13

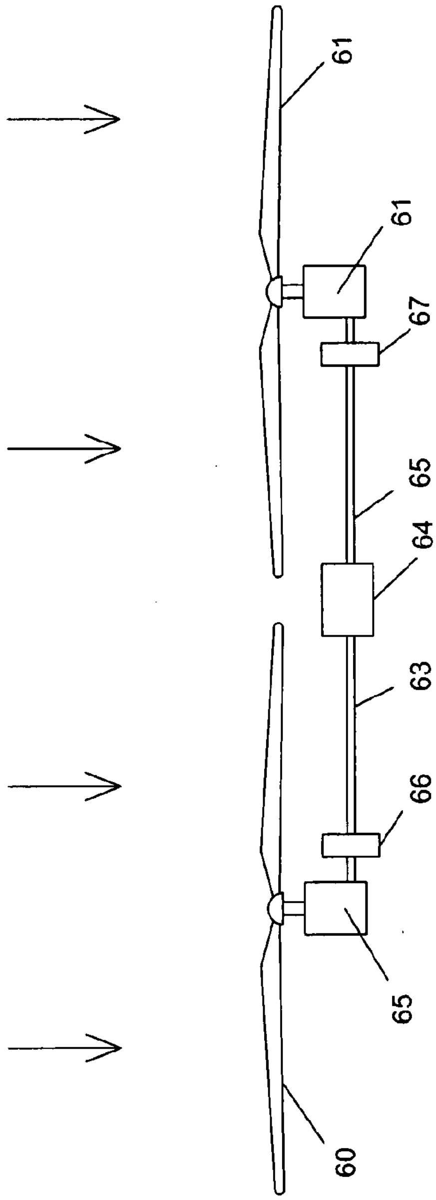


FIGURE 14

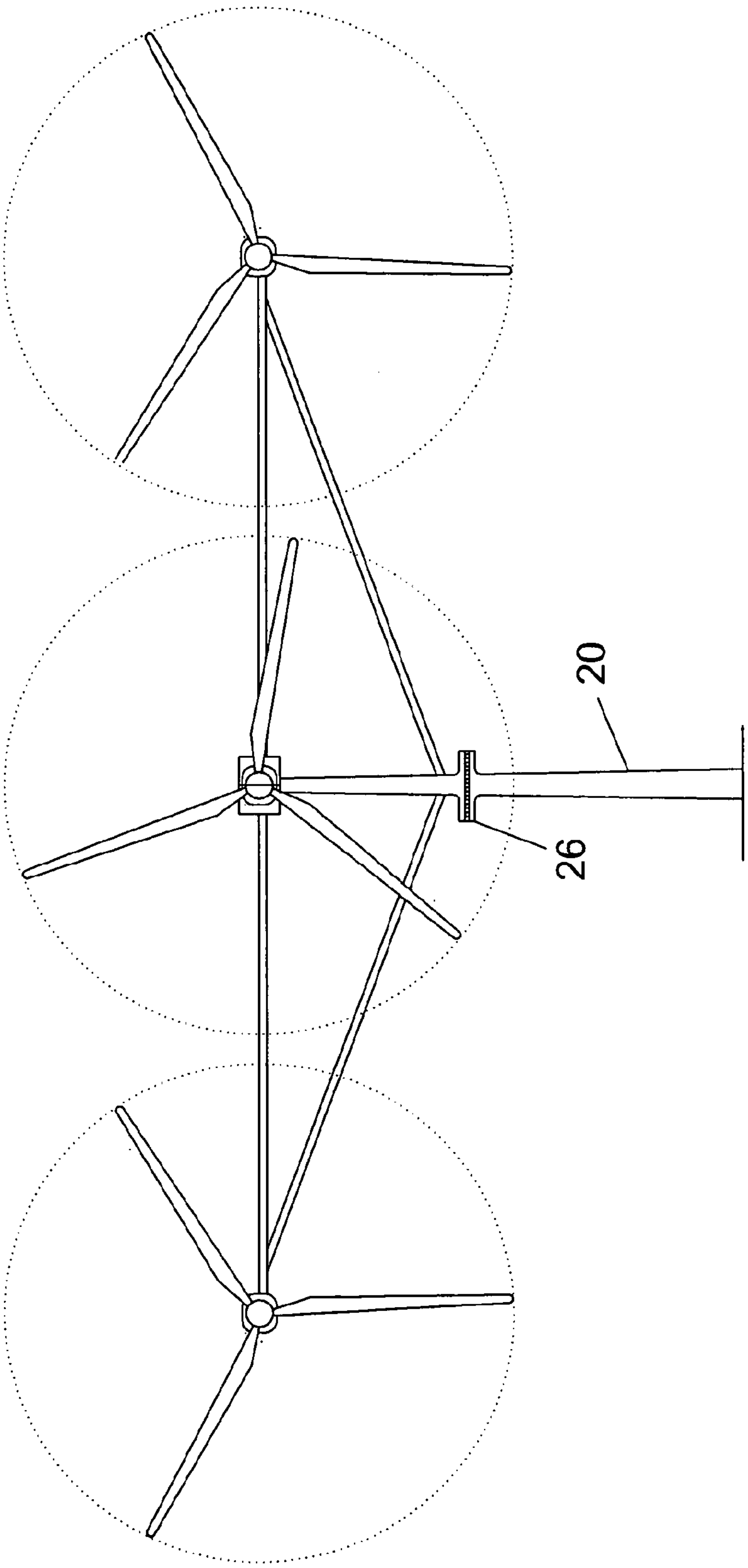


FIGURE 15

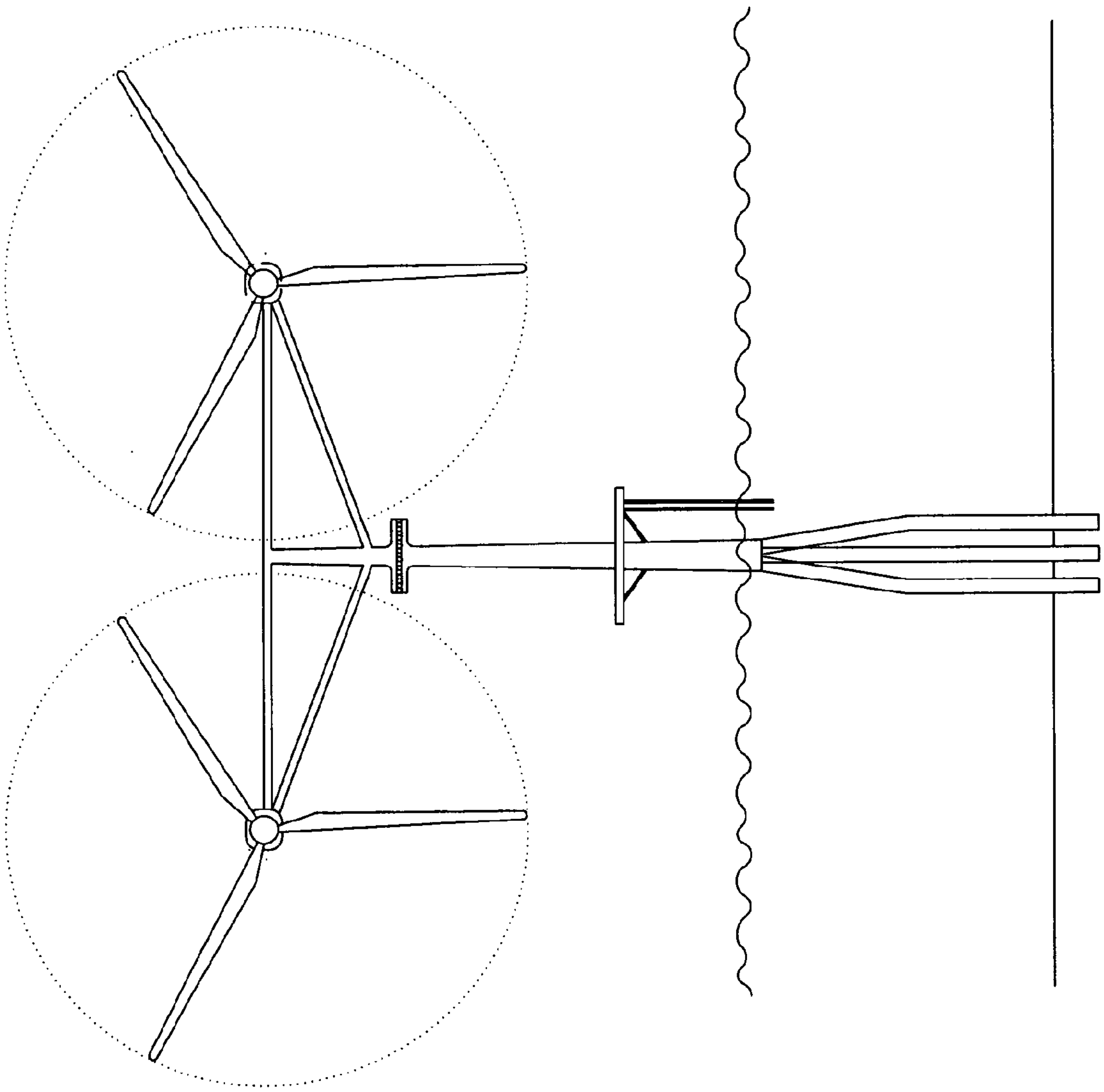
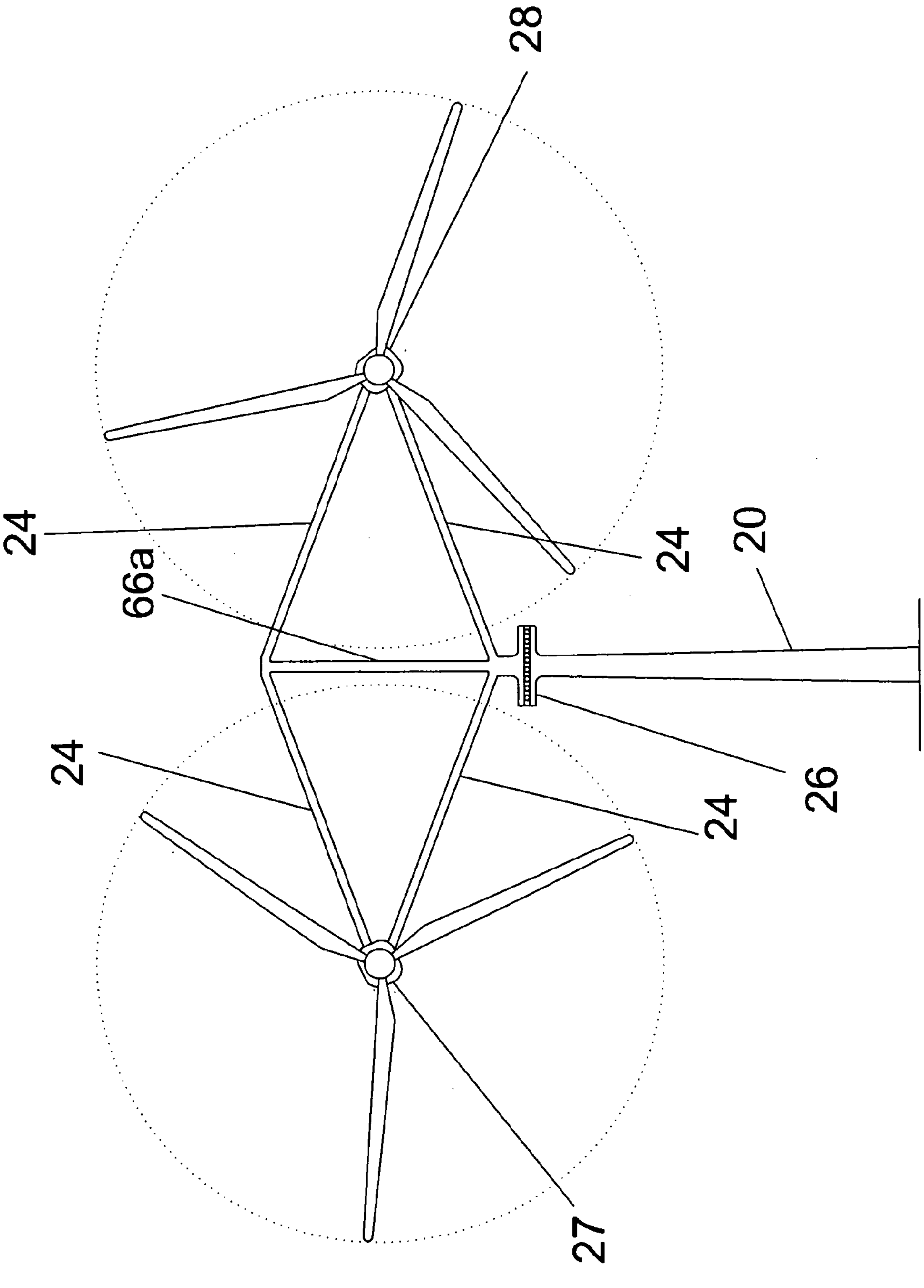


FIGURE 16



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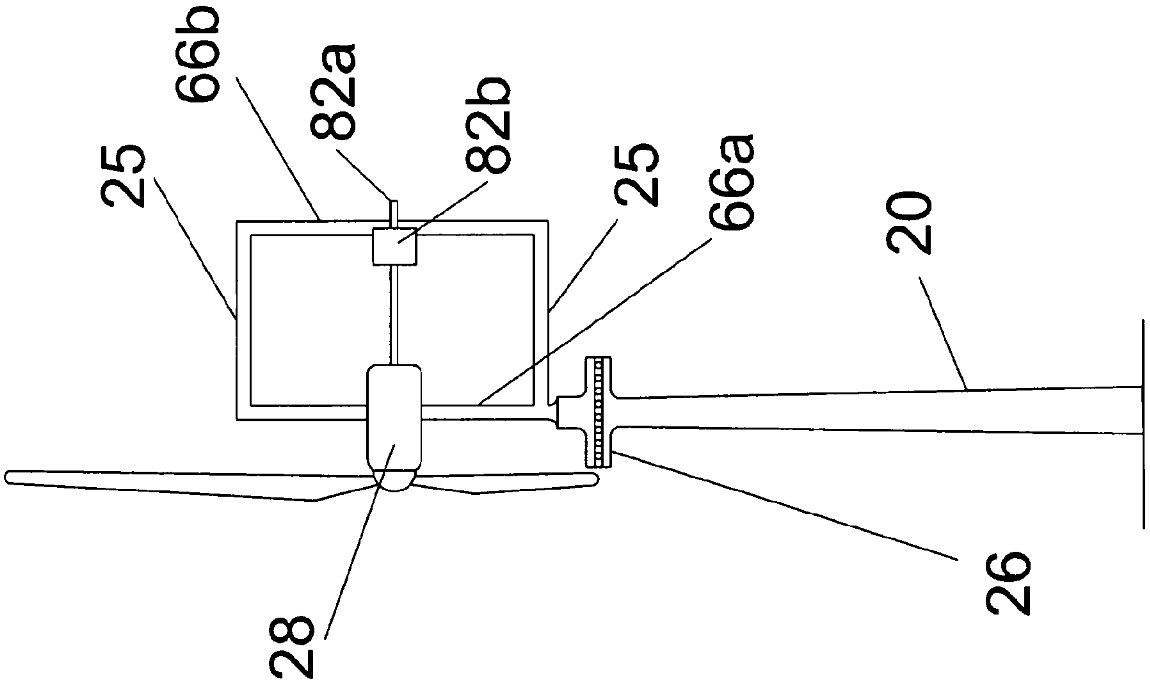

FIGURE 18

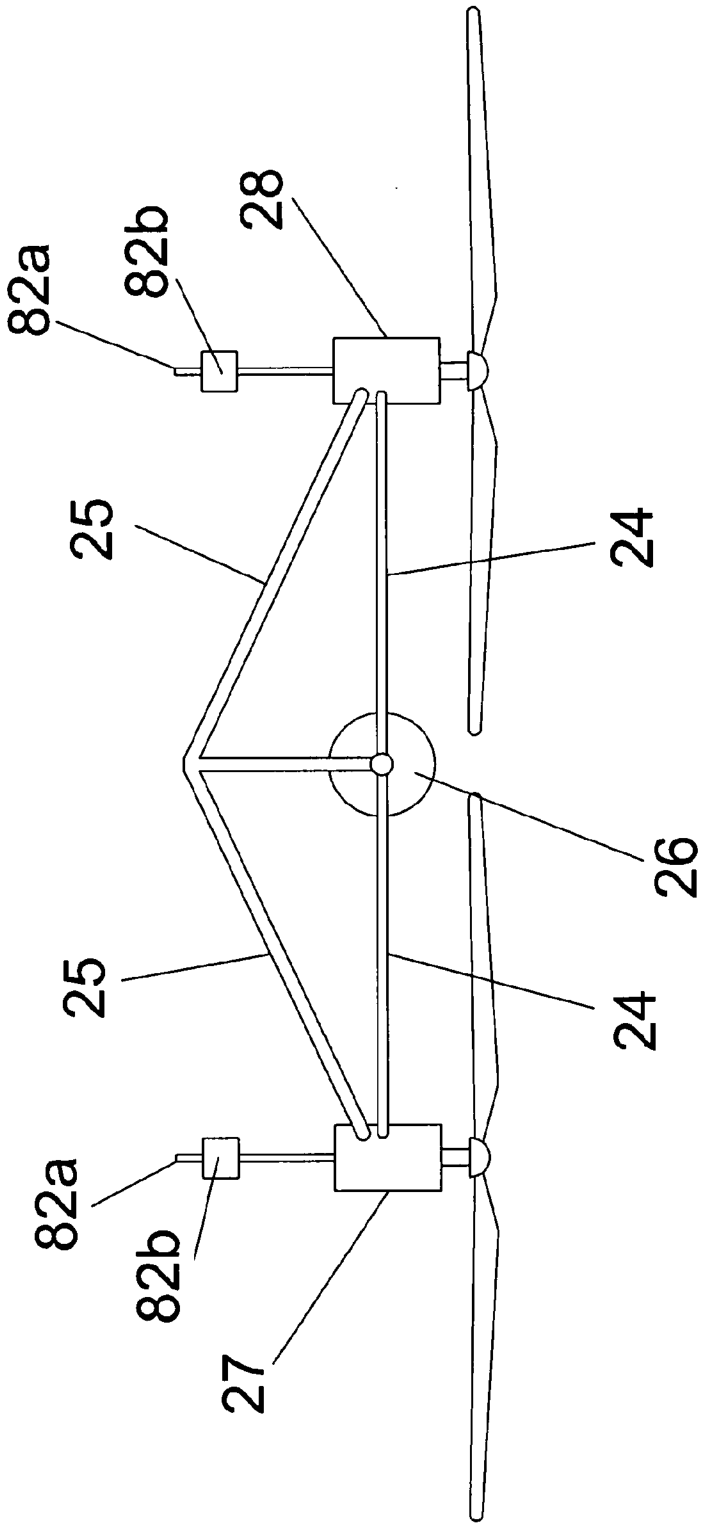

FIGURE 19

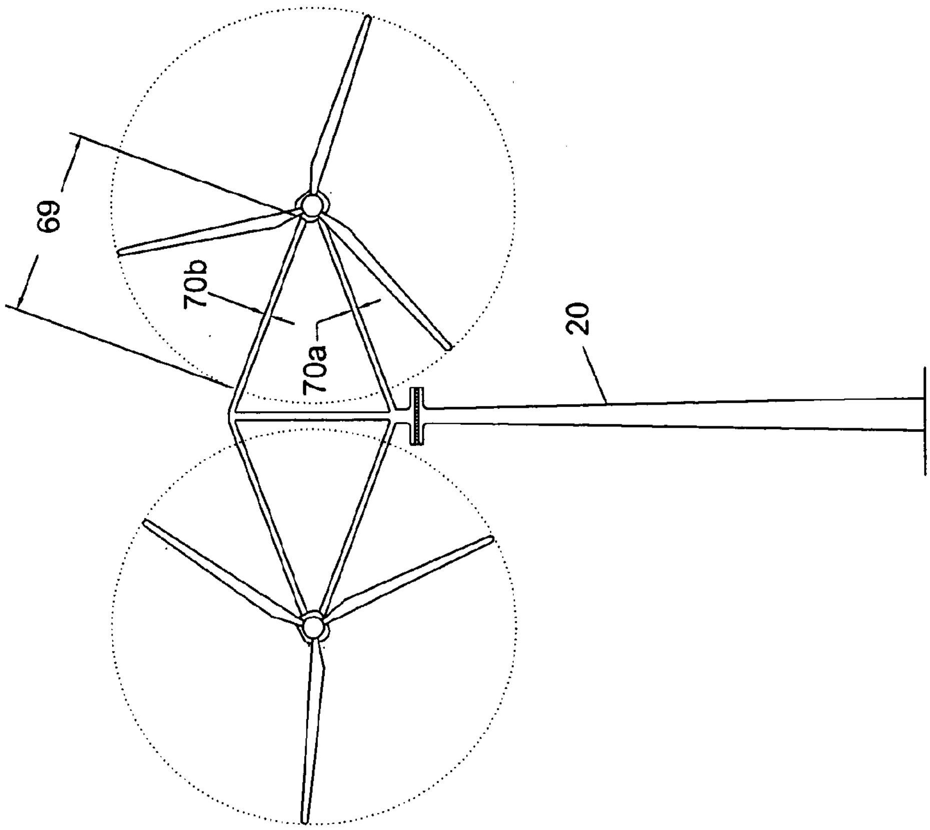

FIGURE 21

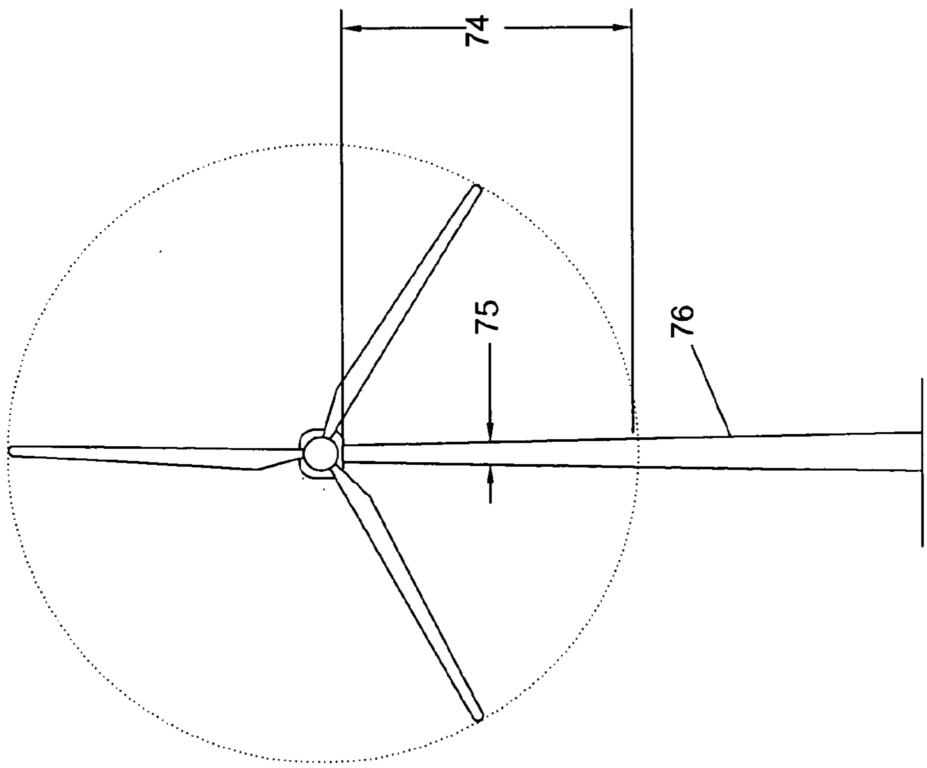

FIGURE 20

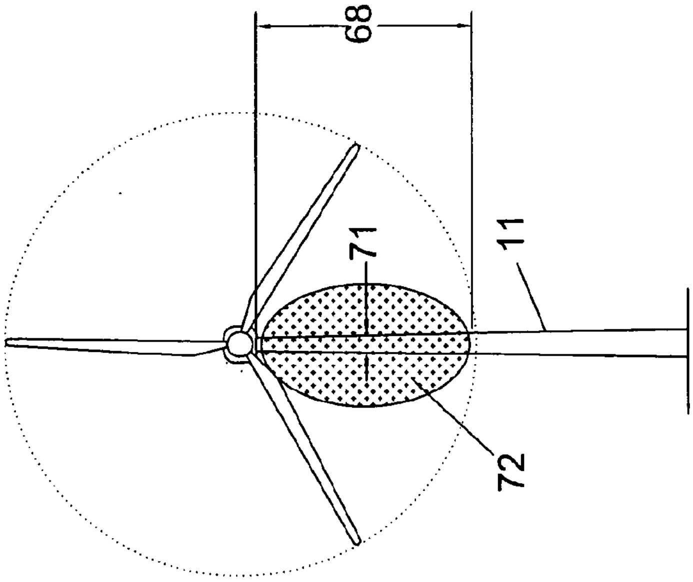

FIGURE 23

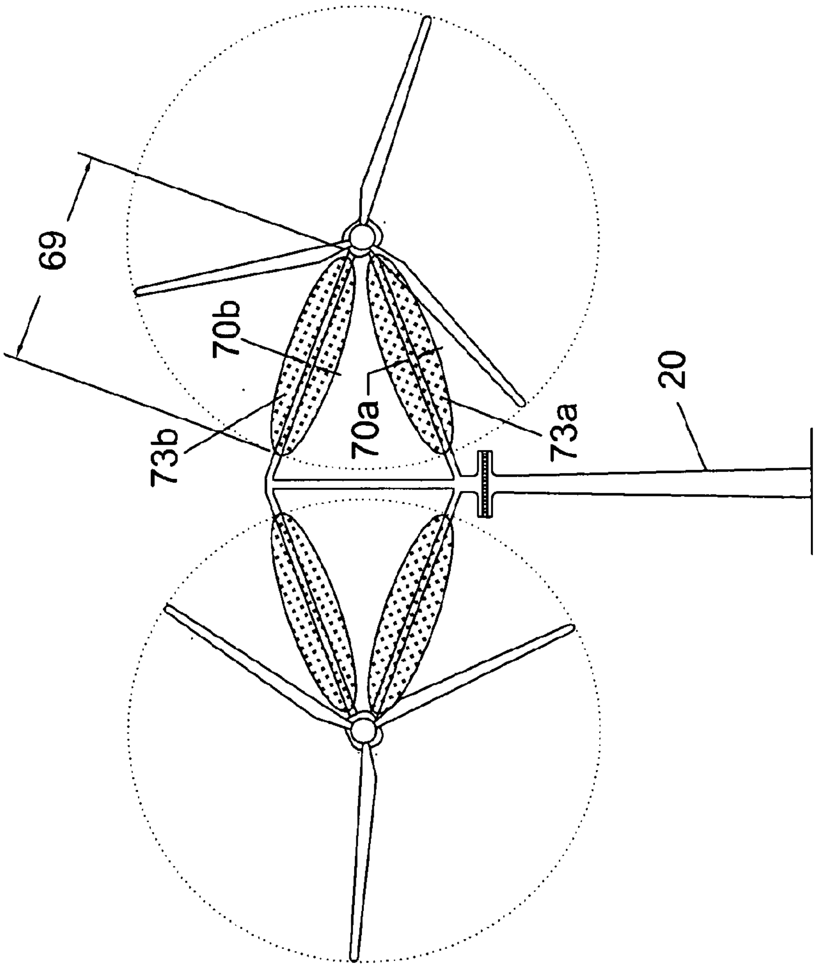

FIGURE 22

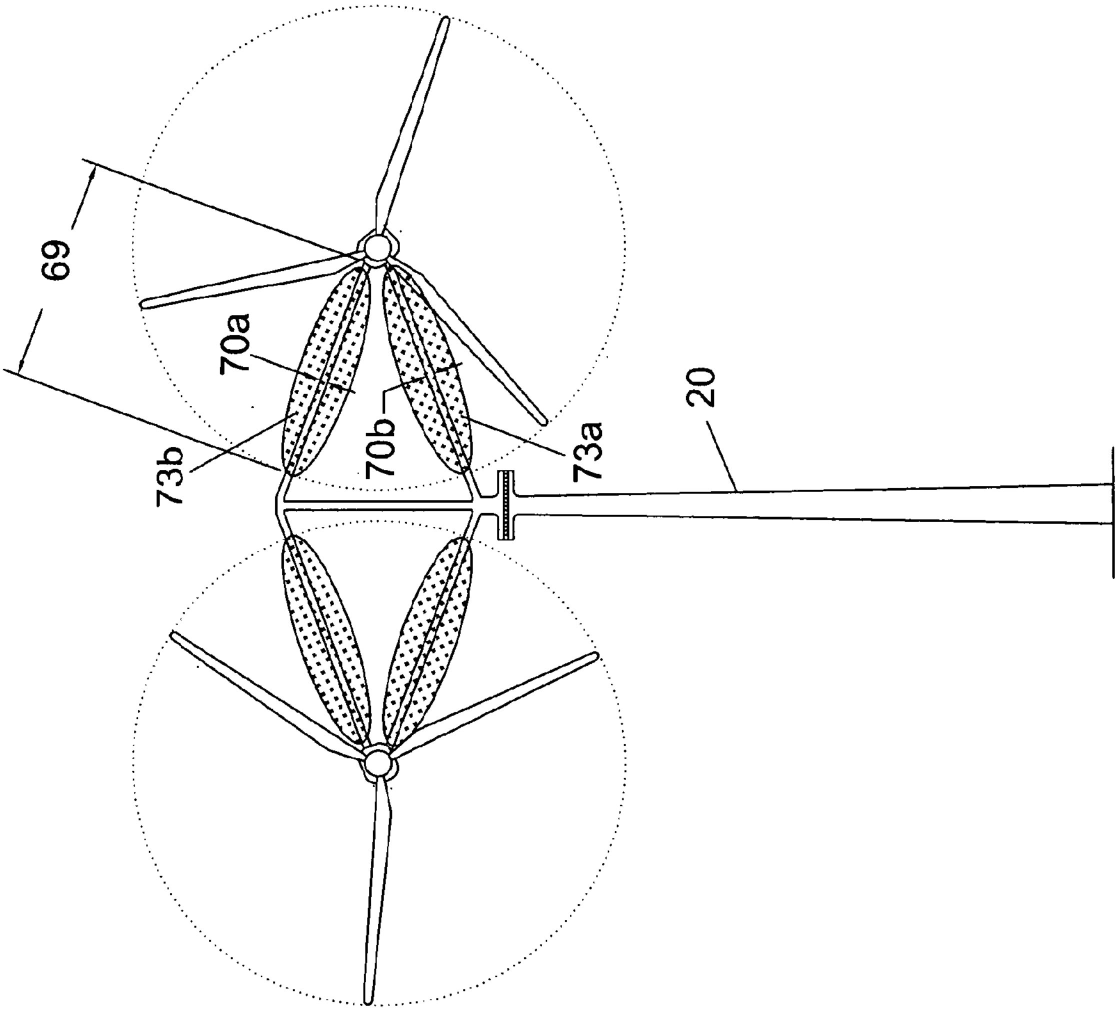

FIGURE 24

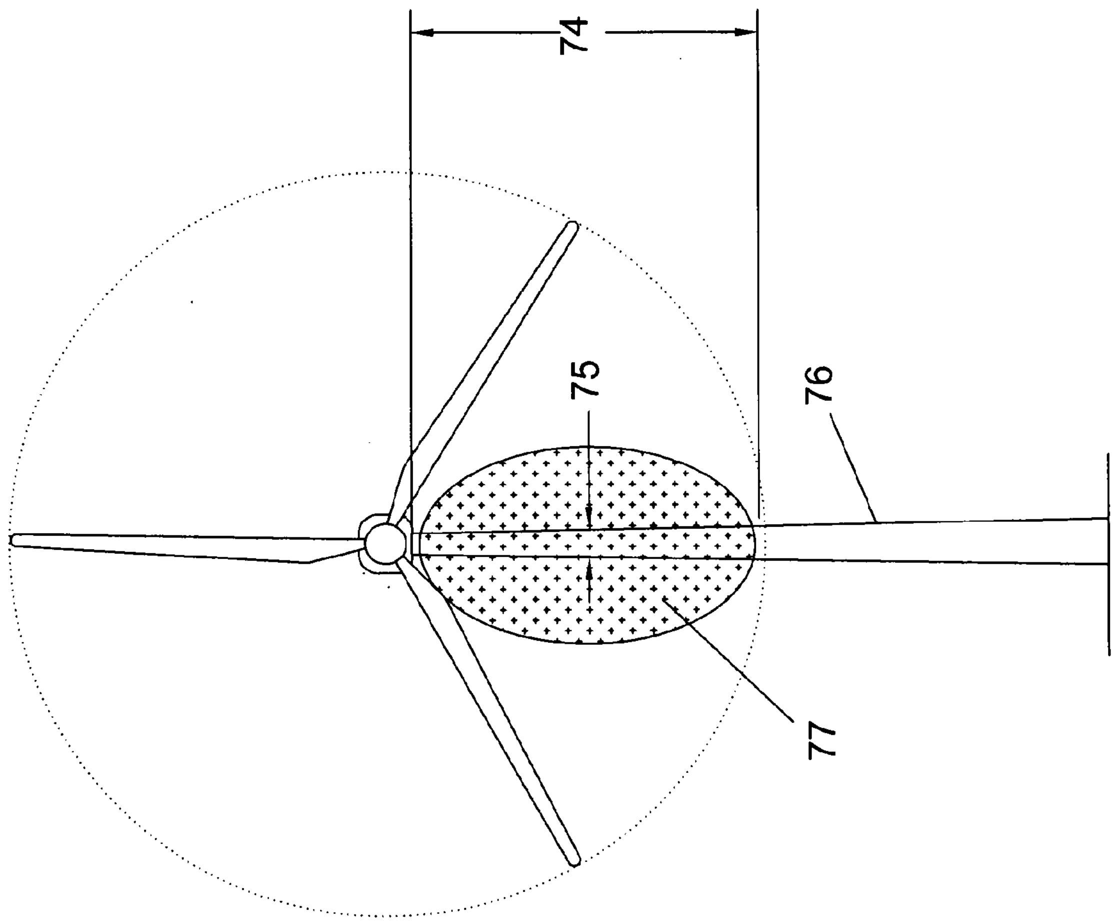

FIGURE 25

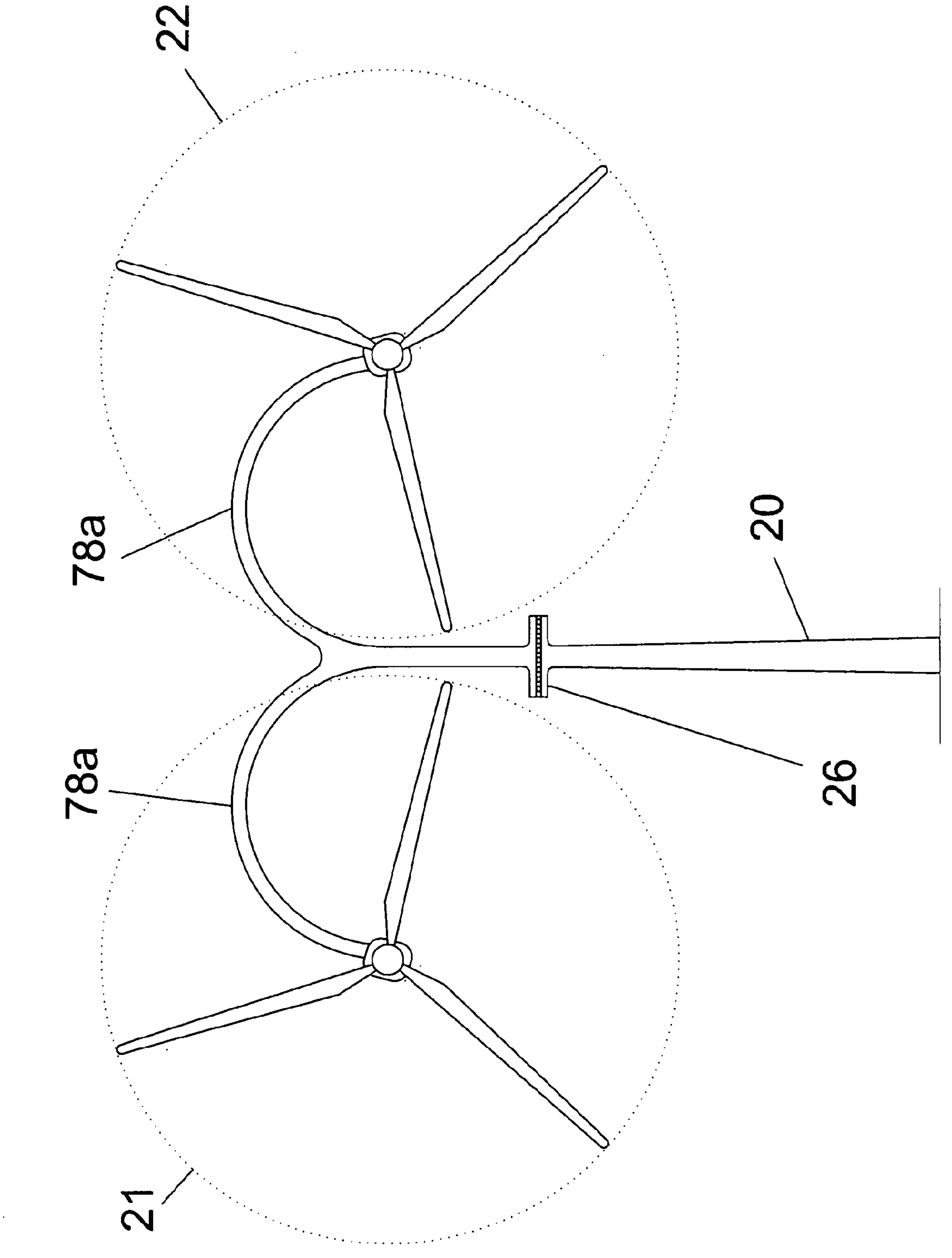

FIGURE 26

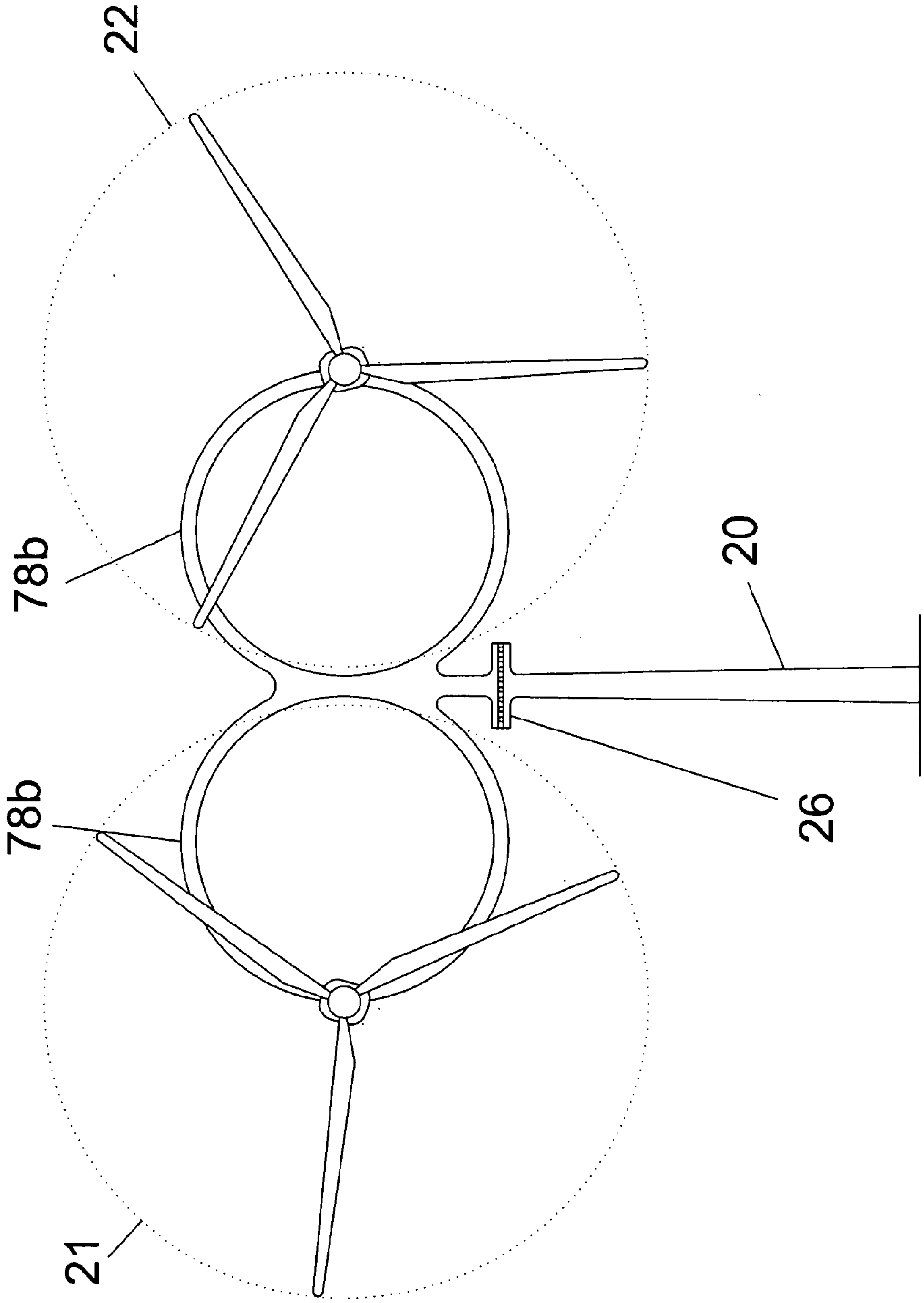

FIGURE 27

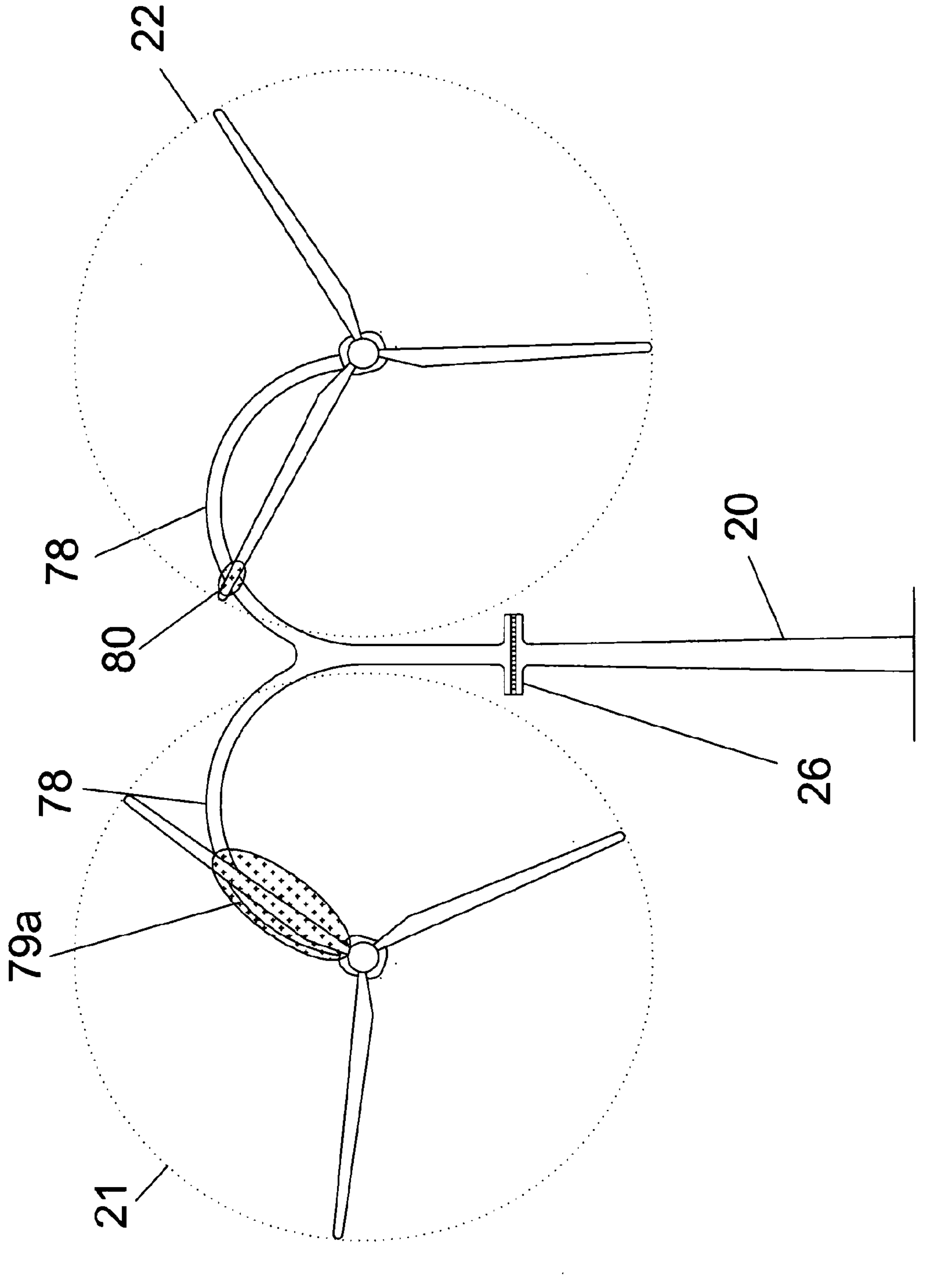

FIGURE 28

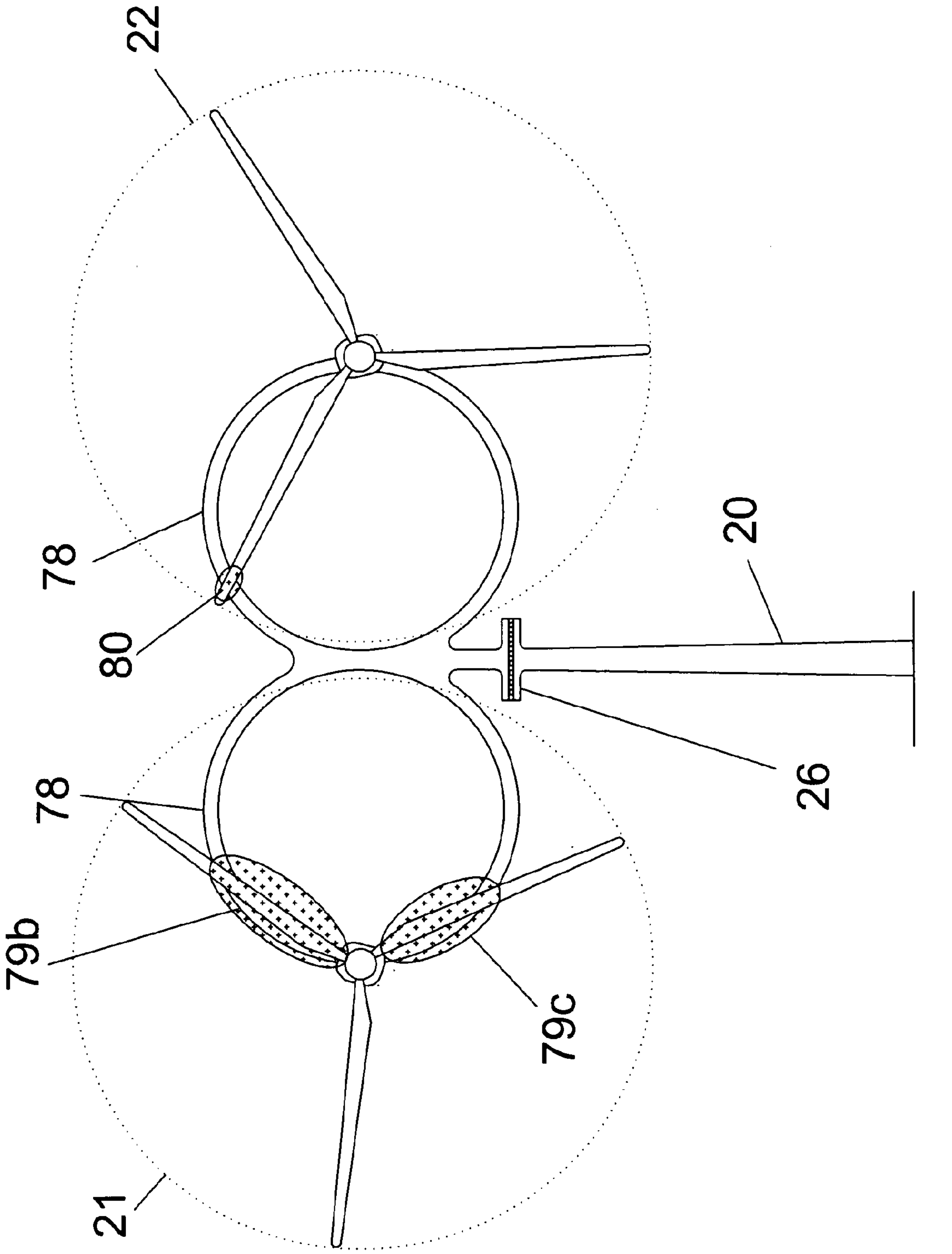

FIGURE 29

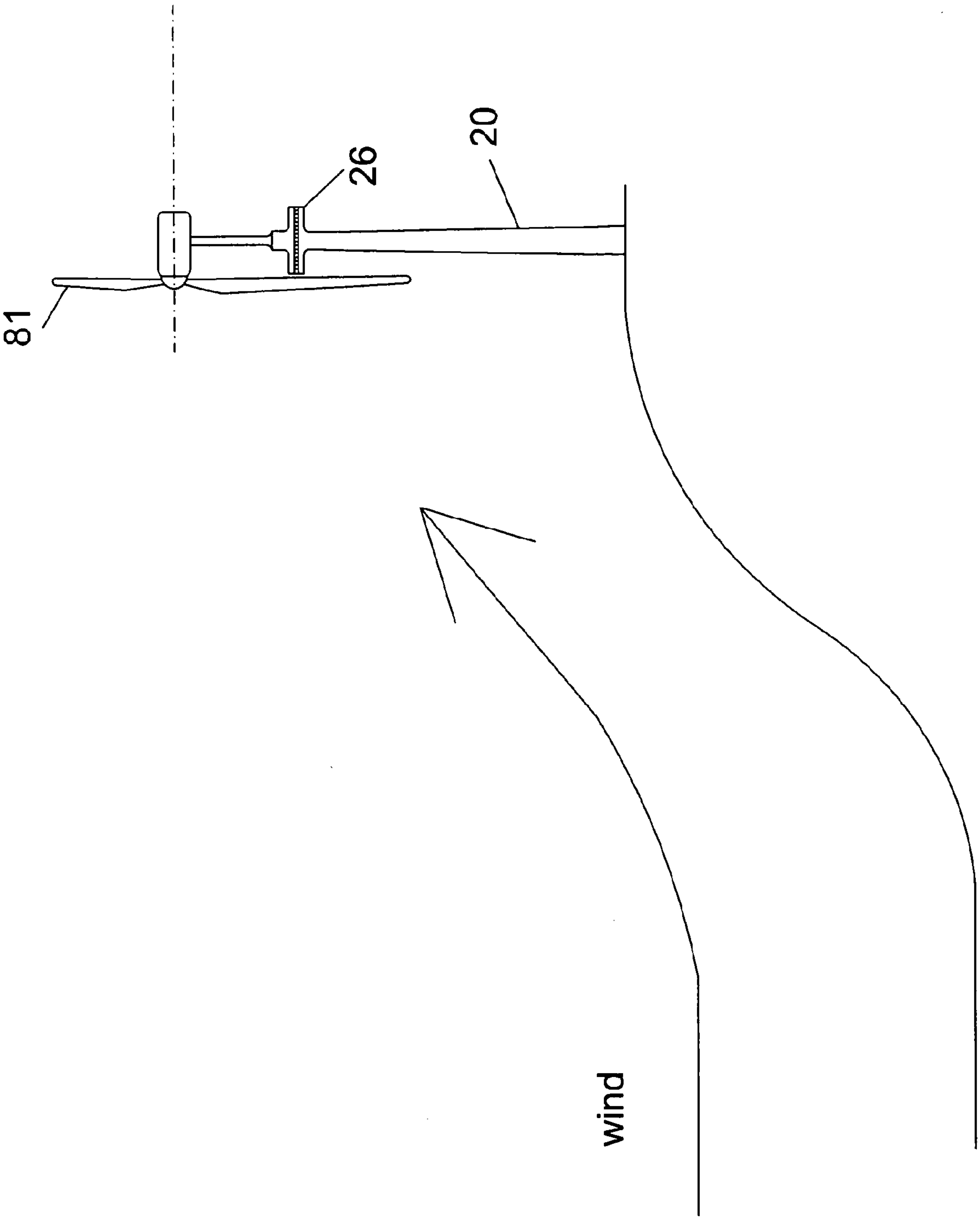

FIGURE 30

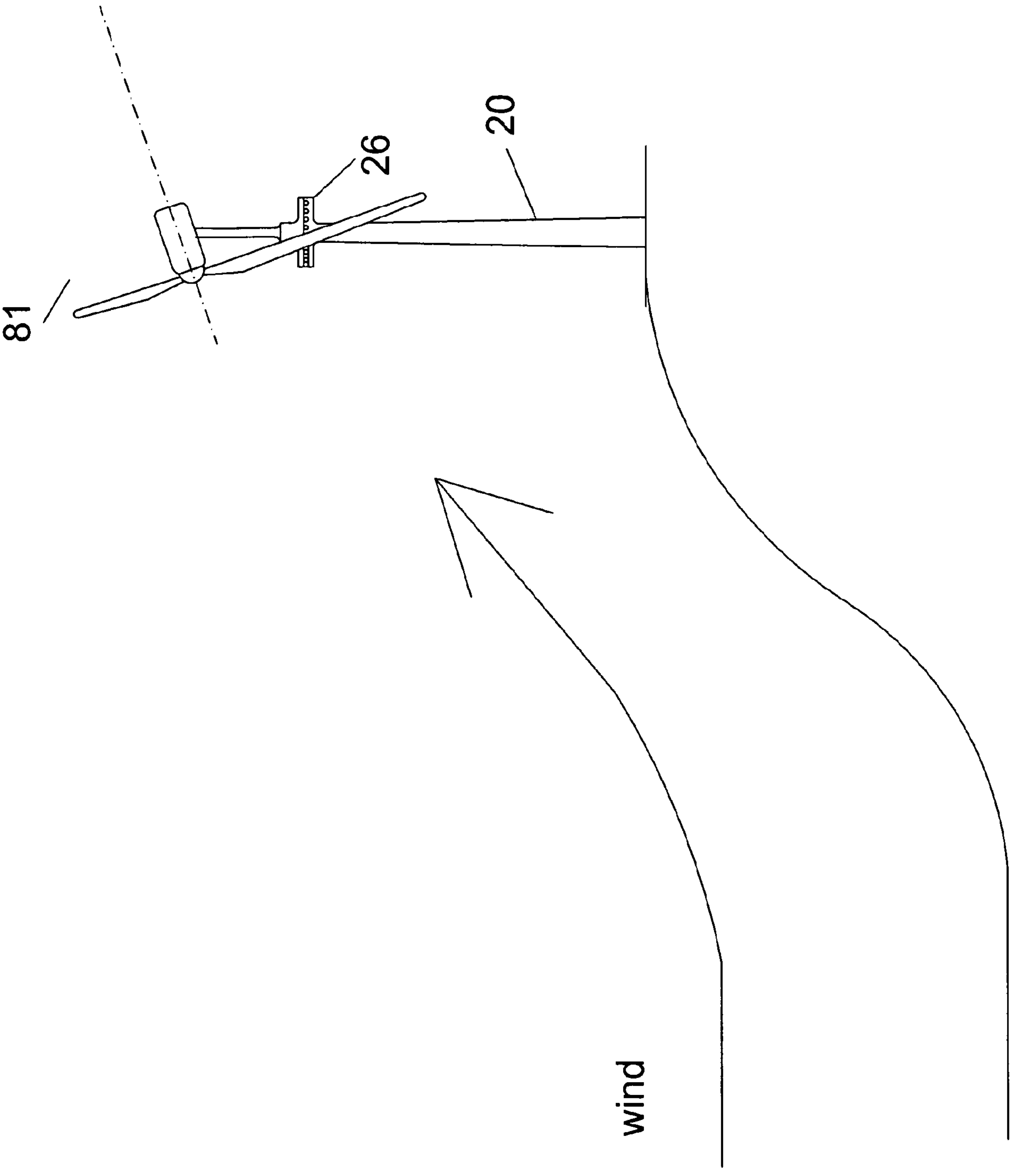

FIGURE 31

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 10/00328

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F03D 9/00 (2010.01)
USPC - 290/44

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)
USPC - 290/44

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 52/27, 40; 290/44, 55; 415/4.1, 4.2, 4.3; 416/9, 10, 16, 31, 36, 40, 131, 132

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST(USPT,PGPB,EPAB,JPAB); Google, Google Patents
Search Terms Used: wind, power, generator, yaw, yawing, pitch, pitching, tilt, multiple, buoyancy, park, parking, rotor, windship.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2003/0168864 A1 (HERONEMUS et al.) 11 September 2003 (11.09.2003), abstract, para [0009], [0012], [0043], [0045], [0065], [0079], [0081]-[0084], [0089], Fig. 1, 3, 12, 13, 20, 21.	1 - 20
Y	US 6,441,507 B1 (DEERING et al.) 27 August 2002 (27.08.2002), abstract, col 5 ln 34-39.	1- 20
Y	US 6,784,566 B2 (THOMAS) 31 August 2004 (31.08.2004), col 2 ln 26-34, Fig. 6.	20
A	US 2006/0138782 A1 (FRIESTH) 29 June 2006 (29.06.2006), entire document	1-20
A	US 2009/0021015 A1 (PEDERSEN) 22 January 2009 (22.01.2009), entire document	1-20
A	US 6,327,957 B1 (CARTER) 11 December 2001 (11.12.2001), entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐

* 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

"T" 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	Date of mailing of the international search report
19 March 2010 (19.03.2010)	30 MAR 2010

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774