WIND TURBINE

TECHNICAL FIELD AND BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to a wind turbine and control system for the wind turbine, and, more particularly, to a wind turbine that may operate at relatively low wind speeds while still generating electricity.

[0002] Conventional wind turbines typically start to operate when the wind speed is at or above 8 mph. This is due in part to the weight of the turbine blades and also in part to the friction in the gears between the turbine blade shaft and the generator. Therefore, current wind turbines do not typically harness energy from wind speeds of less 8 mph. Given that wind speeds below 8 mph represent a significant component of the overall wind speed spectrum in the U.S. and, elsewhere, the current wind turbines overlook a significant potential source of energy.

[0003] Conventional wind turbines also tend to be relatively expensive; difficult to install, maintain, and operate; and not easily integrated into the electrical system of a residential or small business setting. Conventional wind turbines may also become damaged if the wind speeds are excessive.

SUMMARY OF THE INVENTION

[0004] The present invention provides a wind turbine that can harness energy from low wind speeds to generate electricity. Further, the wind turbine can be assembled using relatively simple and inexpensive components and, further, can be constructed so that it can be portable and mounted on top of existing structures. Additionally, the wind turbine may be configured so that there is a significant reduction in noise generated when the wind turbine is operating, even under high wind speeds. Optionally, the wind turbine may be adapted to harness energy wind from beyond the outer periphery of the wind turbine blades to further enhance the efficiency of the wind turbine.

[0005] In one form of the invention, a wind turbine includes a rotary shaft having an axis of rotation, a plurality of turbine blades supported for rotary motion about the shaft, a plurality of magnets, which are supported by and spaced outwardly from the axis of rotation and outwardly from the rotary shaft, and a coil. The blades are mounted to the shaft by a mount that is radially inward of the magnets wherein the magnets have an angular velocity of at least the angular velocity of the blades. Further, the coil is located outwardly from the magnets, and optionally such that the coil surrounds the magnets.

[0006] In another form of the invention, a wind turbine includes a support and a plurality of turbine blades mounted for rotational movement relative to the support. Each of the blades has a proximal end inward of its distal end, with the distal end of each blade having a greater width than its inward proximal ends. Further, each blade has an asymmetrical cross-section which varies along its length.

[0007] In yet another form of the invention, a wind turbine includes a support and a plurality of turbine blades mounted for rotational movement relative to the support. Each of the blades has a proximal end inward of its distal end, with the distal end of each blade having a greater width than its inward proximal ends. Further, each blade has an attack angle that varies along its length, with the greatest attack angle at its distal end and the smallest attack angle at its proximal end.

[0008] According to yet another form of the invention, a wind turbine includes a support and a plurality of turbine blades rotatably mounted relative to the support. Each of the blades is formed from a flexible membrane. Optionally, blades on opposed sides of the support are tied together so that the radial forces acting on the opposed blades are balanced. Additionally, the blades may be tied together by an elastic member or a spring so that the blades may move away from the support under high wind conditions. Further, the blades may be configured to assume a more compact configuration, e.g. fold or compress, to reduce the surface area of the blade and hence the wind turbine's solidity.

[0009] In another form of the invention, a wind turbine includes a turbine wheel with a plurality of wind turbine blades, which is mounted for rotation in a plane, and at least one magnet extending outwardly from the turbine wheel in a direction angled with respect to the plane of rotation of the wind turbine wheel.

[0010] According to yet another form of the invention, a wind turbine includes a wind turbine wheel with an outer rim and a plurality of stators. The stators are generally aligned with at least a portion of the outer rim of the wheel, with at least a portion of the stators being radially inward of the outer perimeter of the outer rim.

[0011] In any of the above turbine, the turbine blades may be formed from a flexible membrane. For example, each blade may include a frame with the flexible membrane applied to the frame. Suitable frames include metal frames, such as aluminum frames, stainless steel frames, or the like. Alternately, the frame may be integrally formed with the membrane. The membrane can be formed from a flexible sheet of material, such as a fabric, including nylon or a KEVLAR®, or from a polymer, such as a plastic. The membrane is then mounted to the frame, for example, by welds, stitches, fasteners or the like.

[0012] Alternately, the blade may be molded from a moldable material, such as plastic, including a glass-filled nylon, polyethylene, a carbon fiber reinforced nylon, or KEVLAR®. For example when molded, the blade may be formed with an integral frame. For example, the blade may be molded with an outer perimeter rim and a thin web that extends between the outer rim, with the rim reinforcing the thin web. Further, the web may be reinforced by ribs that extend across the blade and optionally between two opposed sides of the rim. In this manner, a separate frame may not be needed.

[0013] In addition, the blades may be adapted to reduce the solidity of the turbine. For example, the turbine blades may be configured to assume a more compact configuration when the wind speed increases above a pre-determined wind speed. For example, the blades may be configured to form an

opening in the blade that increases with an increase in wind speed above a predetermined wind speed. In one form the turbine blade is bifurcated with a bifurcated membrane, with one portion of the membrane being fixed and other separating from the fixed membrane in response to the wind speed exceeding the predetermined wind speed.

[0014] In further aspects, the wind turbines may include a spoked wheel with a central hub and a plurality of spokes extending outwardly from the hub, which then support an annular ring or rim at their outer distal ends. The turbine blades are then mounted to the spokes. In this application, the magnets may be mounted to the annular rim of the wheel.

[0015] According to yet further aspects, the magnets may be mounted to the rim and extended from the rim along radii of the spoked wheel frame so that they lie in the same plane as the wheel. In another form, the magnets can be mounted to extend in a direction angled from the plane of rotation of the wheel. For example, the magnets may be mounted to the rim in a generally perpendicular orientation relative to the wheel so that they may extend in a horizontal direction around the axis of rotation of the wheel.

[0016] In other aspects, the stator coil or stator coils are configured with a generally U-shaped cross-section with a channel. Further, the magnets extend into the channel so that the coil straddles or surrounds the magnets on at least two sides. Additionally, the coil may be configured so that one leg of U-shaped cross-section of the coil generates current that is additive with the current generated in the second leg of the U-shaped cross-section of the coil. In this manner, when a magnet passes through the coil, the magnet generates double the electricity in the coil than if the coil was positioned at only one side of the magnet.

[0017] In a further aspect, the stator coil or stator coils are configured to extend at least partially around the circumferential path of the magnets. Optionally, the coil or coils may be extended around the full circumferential path of the magnets.

[0018] Accordingly, the present invention provides a wind turbine that can operate at low wind speeds, for example at wind speeds that are below 8 mph, less than 6 mph, less than 4 mph, and even below 2 mph, for example, at about 0.3 mph.

[0019] According to other aspects, the present invention provides a wind turbine and control system that automatically controls the orientation of the wind turbine and the generation of electrical power therefrom in such a manner so as to avoid damage to the wind turbine and to increase the efficiency of the wind turbine system. The wind turbine system is easy to install in residential and similar type settings and may incorporate one or more conventional parts, such as automobile batteries, to reduce the cost of the overall system.

[0020] According to another aspect, a system for generating electricity from wind is provided. The system includes a wind turbine and a control subsystem for the wind turbine. The wind turbine includes a plurality of blades adapted to rotate about an axis and to thereby generate an output voltage.

The wind turbine has an electrical impedance and the control subsystem has a variable impedance controlled by a controller. The controller extracts power from the wind turbine in a pulsed manner by changing the variable impedance of the control subsystem between levels that are below and above the electrical impedance of the wind turbine.

[0021] According to another aspect, a system for generating electricity from wind is provided. The system includes a wind turbine and a control subsystem. The wind turbine includes a plurality of blades adapted to rotate about an axis and to thereby generate an output voltage. The control subsystem extracts electrical power from the wind turbine in a substantially continuous manner when the wind speed is less than a wind speed threshold, and the control subsystem extracts electrical power from the wind turbine in a pulsed manner when the wind speed is greater than the wind speed threshold.

[0022] According to another aspect, a control system for a wind turbine having a plurality of blades adapted to rotate about an axis is provided. The control system includes a first sensor, a second sensor, a motor, and a controller. The first sensor determines wind direction; the second sensor determines wind speed; and the motor changes an orientation of the rotational axis of the wind turbine. The controller is in communication with the first and second sensors and activates the motor such that the axis aligns with the wind direction when the wind speed is less than a threshold. The controller further activates the motor such that the axis is misaligned with the wind direction when the wind speed is greater than the threshold.

[0023] According to another aspect, a system for generating electricity from wind power is provided. The system includes a wind turbine, a voltage sensor, a switching converter—such as, but not limited to—a buck converter, an inverter, a transfer switch, a battery, and a controller. The wind turbine includes a plurality of blades adapted to rotate about an axis and generate a voltage output. The voltage sensor measures the voltage of the output from the wind turbine. The switching converter is in electrical communication with the wind turbine voltage output and reduces the voltage level of the wind turbine voltage output. The inverter converts direct current into alternating current. The transfer switch selectively couples either an output of the inverter or a utility-supplied source of electrical energy to a distribution panel in the residence or business setting to which the wind turbine is supplying electrical energy. The controller is in communication with the voltage sensor, the buck converter, the battery, and the transfer switch. The controller monitors the charge level of the battery and switches the transfer switch to couple the utility-supplied source of electrical energy to the distribution panel when the charge level of the battery falls below a charge threshold and the output voltage falls below a voltage threshold.

[0024] According to other aspects, the second sensor may be an anemometer physically spaced away from the wind turbine blades, or it may be one or more sensors adapted to measure a speed of the plurality of blades. The controller may further activate the motor such that the amount of

misalignment between the axis and the wind direction increases as the wind speed increases above the threshold. The voltage regulator may supply a regulated voltage to the inverter and one or more batteries. The blades of the wind turbine may have a profile that occupies a relatively large portion of the circular area defined by the rotation of the blades, such as 50% or more, although other levels of solidity may be used. The wind turbine itself may include a plurality of magnets mounted adjacent an outer end of the plurality of blades. The controller may be adapted to automatically couple the battery to the distribution panel upon detecting a loss of utility-supplied power. The controller may also be configured to monitor a charge level of the battery and prevent the battery from experiencing a deep cycle discharge except when the controller detects a loss in the utility-supplied power. The controller may re-charge the battery by applying a substantially constant current to the battery until a threshold level of charge is reached and thereafter supply a substantially constant voltage to the battery after the threshold level of charge is reached. The battery may be a conventional automobile battery, or a plurality of conventional automotive batteries electrically coupled together in any suitable manner. The control subsystem may change its electrical impedance in a pulsed manner that alternates between slowing the wind turbine down to a low speed threshold and allowing the wind turbine to regain speed up to an upper speed threshold, and which repeats in a like manner.

[0025] According to still other aspects, the controller may transmit electricity generated by the wind turbine directly to the inverter if the level of voltage generated by the wind turbine exceeds a voltage threshold. The inverter may convert direct current into alternating current having a voltage of substantially 120 volts so that the voltage may be supplied directly to residences and business in North American homes or small businesses. In other embodiments, the inverter may be configured to convert the direct current into alternating current having a voltage equal to the customary household voltage supplied to the residences of a particular country or geographical region (e.g. 230V for European residences). The controller may include a display panel that displays one or more of the following: wind speed, wind direction, battery charge, cumulative energy generated to date, and voltage being generated by the wind turbine.

[0026] These and other objects, advantages, purposes, and features of the invention will become more apparent from the study of the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] FIG. 1 is an elevation view of a wind turbine of the present invention;

[0028] FIG. 2 is a side end view of the turbine of FIG. 1;

[0029] FIG. 3 is an elevation view of another embodiment of the wind turbine of the present invention;

[0030] FIG. 4 is a side end view of the turbine of FIG. 3;

[0031] FIG. 5 is an enlarged view partial fragmentary view of the stator coil of FIG. 4 illustrating the magnet in the channel formed by the stator coil;

[0032] FIG. 6 is an elevation view of another embodiment of the wind turbine of the present invention with a spoked wheel;

[0033] FIG. 7 is an enlarged view of the wheel and magnet mounting arrangement;

[0034] FIG. 8 is an enlarged view of the wind turbine blade mounting details;

[0035] FIG. 9 is an elevation view of the spoked wheel with the turbine blades removed for clarity;

[0036] FIG. 10 is an enlarged view of one mounting arrangement of the magnet to the rim of the spoked wheel;

[0037] FIG. 11 is a similar view to FIG. 6 with the coil cover and blades removed for clarity;

[0038] FIG. 12 is an enlarged view of the stator coil mounting arrangement;

[0039] FIG. 12A is a schematic drawing of the stator coils and their interconnecting circuit;

[0040] FIG. 13 is another enlarged view of the stator coil mounting arrangement and magnet mounting arrangement;

[0041] FIG. 14 is an enlarged view of a turbine blade;

[0042] FIG. 14A is an enlarged view of the turbine blade frame;

[0043] FIG. 15 is an elevation view of another embodiment of the turbine blade;

[0044] FIG. 15A is a side view of the turbine blade of FIG. 15;

[0045] FIG. 15B is an enlarge view illustrating the turbine blade of FIG. 15 mounted to the turbine wheel;

[0046] FIG. 16 is an enlarged view of another embodiment of the turbine blade that incorporates a partial membrane mounted to the turbine blade frame;

[0047] FIG. 17 illustrates the turbine blade of FIG.16 with a second partial membrane support mounted to the frame for movably mounting a second partial membrane to the frame;

[0048] FIG. 17A is a plan view of the membrane support of FIG. 17;

[0049] FIG. 18 illustrates the turbine blade of FIG. 16 with the second partial membrane mounted to the frame;

[0050] FIG. 19 illustrates the turbine blade of FIG. 18 with a biasing member for biasing the second partial membrane in a position that provides the maximum solidity to the turbine blade;

[0051] FIG. 20 is a side end elevation view of another embodiment of the wind turbine of the present invention;

[0052] FIG. 21 is an enlarged view of the turbine wheel and magnet mounting arrangements;

[0053] FIG. 22 is an enlarged view of the magnet mounting arrangement;

[0054] FIG. 23 is an enlarged partial view of the turbine blade wheel of FIG. 21 illustrating the magnets and stator mounting arrangements;

[0055] FIG. 24 is an enlarged view of the another embodiment of the wheel and stator mounting arrangement;

[0056] FIG. 25 is an enlarged view of the stator coil and magnet mounting details;

[0057] FIG. 26 is an elevation view of another embodiment of the wind turbine of the present invention;

[0058] FIG. 27 is a side elevation view of the wind turbine of FIG. 26;

[0059] FIG. 28 is an elevation view of the another embodiment of the wind turbine of the present invention incorporating a wind concentrator mounted to the windward facing side of the wind turbine;

[0060] FIG. 28A is an enlarged fragmentary view of the stator coil assembly and magnet mounting details to the turbine wheel;

[0061] FIG. 28B is another enlarged fragmentary view of the stator coil assembly and mounting details;

[0062] FIG. 28C is an enlarged fragmentary view of the wind turbine frame and mounting details for the wind concentrator;

[0063] FIG. 28D is an enlarged fragmentary view illustrating the turbine blades coupled together by a tie support and of the wind turbine frame mounting details;

[0064] FIG. 29 is an enlarged fragmentary view illustrating a lateral support or guide for the turbine wheel;

[0065] FIG. 29A is an enlarged front elevation view illustrating another embodiment of a lateral support or guide;

[0066] FIG. 29B is a rear elevation view of the lateral support or guide of FIG. 29A also illustrating the magnet mounting details to the turbine wheel;

[0067] FIG. 30 is an elevation view of the cover of the wind turbine of FIG. 28;

[0068] FIG. 30A and 30B are perspective views of two sections of the cover of FIG. 30;

[0069] FIG. 30C is a cross-section view of the cover of FIG. 30;

[0070] FIG. 31 is an elevation view of another embodiment of the wind concentrator mounted to the windward facing side of the wind turbine with optional stabilizers;

[0071] FIG. 32 is a schematic drawing of the wind turbine of the present invention mounted on top of a dwelling; and

[0072] FIG. 33 is a chart illustrating a Class 4 wind distribution.

[0073] FIG. 34 is a front elevational view of an electrical generation system including a wind-turbine and a control system;

[0074] FIG. 35 is a side, elevational view of the wind-turbine of FIG. 34;

[0075] FIG. 36 is a front, elevational view of a residence and wind turbine showing an illustrative environment in which the electrical generation system may be used;

[0076] FIG. 37 is a diagram showing interconnections of various components of a control system for a wind turbine;

[0077] FIG. 38 is more detailed diagram of the control system of FIG. 37;

[0078] FIG. 39 is a detailed diagram of several internal components of a charge controller;

[0079] FIG. 40 is a diagram of one embodiment of an electrical generation system showing more components than the view of FIG. 34;

[0080] FIG. 41 is a diagram of the generator and generator control structures of the system of FIG. 40;

[0081] FIG. 42 is a diagram of the control system of the system of FIG. 40;

[0082] FIG. 43 is a chart showing various states that may be assumed by any of the electrical generation systems described herein;

[0083] FIG. 44A is a chart illustrating an arbitrary wind speed over a period of time;

[0084] FIG. 44B is a chart illustrating power that may be generated by an embodiment of the wind turbine system disclosed herein when experiencing the wind speeds shown in FIG. 44A; and

[0085] FIG. 44C is a chart illustrating pulsed power that may be generated by another embodiment of the wind turbine system disclosed herein when experiencing the wind speeds shown in FIG. 44A.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0086] Referring to FIG. 1, the numeral 10 generally designates one embodiment of a wind turbine of the present invention. As will be more fully described below, wind turbine 10, as well as the other wind turbines described herein, may be configured to operate at low wind speeds. For example, the wind turbines can be configured to operate at wind speeds that are below 8 mph, below 6 mph, below 4 mph, below 2 mph, for example, and even as low as about 0.3 mph. As will be understood, this is partially achieved by forming the wind turbine from low weight wind turbine blades, and which therefore have low inertia, and also by providing a gearless turbine. Although a gearless turbine is initially described, it should be understood that a geared turbine may also be used. In addition, by mounting magnets at a location with increased angular speed for a given wind speed over conventional wind turbines, increased electrical generation can be realized for the same wind speed over a conventional wind turbine and, further, can be realized by harnessing magnetic flux from both sides of the magnet.

[0087] Referring to FIGS. 1 and 2, wind turbine 10 includes a frame 12 and a base 14. Frame 12 and base 14 may be formed from suitable metal components, including aluminum or stainless steel components, depending on their application. In some applications composite materials may also be suitable. Frame 12 includes an outer perimeter or annular member 18 and brace members 20, which are supported by the perimeter member 18 and provide a mounting surface for the wind turbine blade assembly 22. Turbine blade assembly 22 includes a hub 24, such as a central disk or plate, and a plurality of turbine blades 26 that are mounted to hub 24 and extend radially outwardly from hub 24, which is mounted to frame 12, namely at brace members 20, by a shaft 22a. Shaft 22a is journaled or rotatably supported in brace members 20, for example, by bearings 22b, and rotatably mounts hub 24 and blades 26 inwardly of perimeter member 18. Therefore, as noted above, the connection between

the blade assembly and the supporting structure for the blade assembly is gearless, though as noted a gear may be included.

[0088] Also mounted to shaft 22a is a plurality of arms 28 that support magnets 30. Suitable magnets include nickel plated neodymium iron boron magnets. The size of the magnet may vary but a suitable size includes a 2 inch by 2 inch by ½ inch thick magnet, or may include thicker magnets, such as about 0.7", 0.8" or 1.0" thick magnets. As will be more fully described below, magnets 30 are positioned in relatively close proximity to a stator coil assembly 32, which is supported in perimeter or annular member 18 so that when the turbine blade assembly 22 rotates with shaft 22a, arms 28 and magnets 30 will similarly rotate to thereby induce current flow in the coils of the stator coil assembly.

[0089] In the illustrated embodiment, turbine blade assembly 22 includes six blades 26, which are evenly spaced around shaft 22a. The diameter of the turbine blade assembly may be varied depending on the application, but for home use, including roof-top mountings, or even commercial use, a diameter of about 6 feet has been found to balance aesthetics and mounting logistics, with electrical generation, though larger or smaller sizes can be used. For other applications, including for example marine applications where the turbine is used to recharge a boat battery, for example, the size may be smaller. Additionally, the number of blades and magnets may be varied. As will be more fully appreciated from the following description, in addition to being able to make the wind turbine compact in size, the weight of the wind turbine may be significantly less than conventional wind turbines. For example, the weight may be less than 150 lbs., less than 125 lbs, or less than 100 lbs depending on the size.

[0090] Further, the blades may be designed with aerodynamic profiles so as to optimize energy transfer from the wind to the rotating turbine blade system. For example, such optimized aerodynamic blade profile may employ tapering of the blade extremity to reduce the wind shear and blade deflections at high speeds. While suitable blades may include commercially available blades, which are commonly used in conventional turbines, the blades may alternately be rectangular bars with a wind attack angle between 5° and 10°, which may offer more efficient operation at low wind speeds and, further, can be made at lower cost than conventional blades. Further, as will be more fully described below the blades may have a varying wind attack angle along its wind facing edge. It should be understood that the blade design selection and attack angle can be varied for a given turbine size and wind speed operating regime. Additionally, the shaft may be configured to offer minimal drag to the wind and can be made of an aerodynamic cross-sectional profile, including a round cross-section, depending on the wind regimes and weight considerations.

[0091] As shown in FIG. 2, magnets 30 are positioned so that they extend into perimeter frame member 18 and into the stator coil assembly. In this manner, when shaft 22a rotates about its rotational axis, the magnets will translate relative to the stator coil assembly and thereby induce current flow in the coils of the stator coil assembly. For further details of the coils in the stator coil assembly, reference is made to U.S. Patent applications serial numbers 12/138,818 and 12/698,640, both entitled

TURBINE ENERGY GENERATING SYSTEM, filed June 13, 2008 and February 2, 2010, respectively, by Imad Mahawili, Ph.D, the disclosure of both of which are hereby incorporated herein by reference in their entirety.

[0092] Arms 28 may be formed from a transverse rod 35, such as a metal rod, including an aluminum rod, which as noted is supported by shaft 22a of turbine blade assembly 22. In this manner, rod 35 is independent from turbine blades 26 but rotates in unison with the respective blades by virtue of rotation with shaft 22a. While only two arms or one rod is illustrated, it should be understood that more than one rod and one set of magnets may be used to double, triple or quadruple the number of magnets in the turbine. However, it should be noted that with an increased number of magnets, the weight of the rotating system is increased. As a result, with an increased number of magnets, the wind speed at which the turbine can start generating power may be increased.

[0093] By placing the magnets at the ends of the rod, the turbine blades are allowed to deflect under the high wind speeds without affecting the accuracy and placement of the magnets within the stator housing, which may simplify operation and extend electricity generation performance. As will more fully described below, however, the magnets may be supported at the distal ends or tips of the respective turbine blades by a rim or ring that is mounted to the turbine blades, which would reduce the blade deflections and which is more fully described below.

[0094] Referring to FIGS. 3 and 4, the number 110 generally designates another embodiment of a wind turbine of the present invention. Turbine 110, similar to turbine 10, includes a frame 112 and a base 114. Frame 112 and base 114 may be also be formed from suitable metal components, including aluminum or stainless steel components, or in some applications composite materials may also be suitable. In the illustrated embodiment, base 114 includes a fixed base portion 114a and a rotatable base portion 114b to which frame 112 is mounted. In this manner, the frame may be repositioned, for example, to reposition the turbine blades relative to the wind. Suitable control systems for controlling the position of turbine blade assembly and frame, as well as managing the electrical energy generated, are described in greater detail below.

[0095] Frame 112 includes an annular member 118 and two annular frame members 120a and 120b, which support annular member 118 on base 114, and more specifically on rotatable base portion 114b. Frame members 120a and 120b also support turbine blade assembly 122 and, similar to members 20, include bearings 122b for supporting shaft 122a of turbine blade assembly 122. Annular member 118 also similar to the previous embodiment supports a stator coil assembly 132, which is supported radially outward of turbine blade assembly 122, and more specifically radially outward of turbine blades 126.

[0096] In the illustrated embodiment, frame members 120a and 120b comprise wire fame members formed from, for example, heavy gauge metal wire or small diameter rods, such as aluminum wire or rods, that form two concentric annular members 134a and 134b, which support a plurality of

radial arms 136. Radial arms 136 in turn support bushings 122b that rotatably support shaft 122a of turbine blade assembly 122. As best seen in FIG. 4, the outer annular members 134a are then mounted to movable base portion 114b of base 114, on for example a pair of posts 114c. For example, annular members 134a may be welded or otherwise fastened to posts 114c.

[0097] Annular member 118 is mounted between frame members 120a and 120b, inwardly of outer annular frame member 134a. Similarly to the previous embodiment, magnets 130 are mounted to arms 128, which are mounted to shaft 122a, such that magnets 130 extend into the stator coil assembly 132. In addition, with this configuration, magnets 130 have an angular velocity greater than the angular velocity of the hub that mounts turbine blade to shaft 122a and equal or greater than the angular velocity of the turbine blades. As noted in reference to the first embodiment, the arms rotate with the shaft 122a and are therefore rotated when the turbine blades rotate.

[0098] Referring to FIG. 5, annular member 118 is mounted to frame members 120a and 120b by fasteners and forms a stator coil assembly housing 140 for stator coil assembly 132. Housing 140 comprises a generally annular channel-shaped member that may extend around the full circumference of the turbine wheel, as shown so that it fully encircles the path of the turbine blades or just around a portion of the path. For example, as will be more fully described below, the stator coil assembly may extend over only a portion of the path of the turbine wheel and may be positioned at top most position (12 o'clock position) of the blades or at the bottom most position (6 o'clock) or in between.

[0099] Stator coil assembly housing 140 as noted has a generally channel-shaped cross-section and forms a channel 140a with an open side 140b into which the magnets 130 extend. Housing 140 is formed from a non-magnetic material, for example, plastic. The internal spacing between the opposed stator housing side walls is sized to minimize the gap 140c, for example an air gap, between the respective side wall of the stator housing and the respective magnet to reduce the attenuation of the flux induced by the rotating magnets.

[00100] The stator coil assembly 132 includes a plurality of coils formed from a conductive wire, such as copper or aluminum wire. For example, the coils may be made from a double-loop copper wire of gauges in a range of about ten to twenty-six, which supported inside housing 140. The copper wire gauge can be varied depending on the turbine size and power output design requirements.

[00101] As described in the referenced application, the coils are formed from a conductive wire that is wound in a manner to increase the electric generation efficiency. This achieved at least in part by configuring the coil to straddle and extend over the two major surfaces of the magnets. In this manner, flux from both sides (major surfaces) of the magnet is harnessed. As described in the above referenced application, in order for the current to be additive, the coils include two leg portions 150a and 150b that straddle the magnet, which are interconnected by a turn or cross-over portion 150c, which cross-over portion allows the electrical current flow induced in both legs 150a and 150b to be additive. Further as best seen in FIG. 5, in order to optimize additive current flow, the magnets are

positioned to extend far enough into the channel formed by the coil loops so that they are aligned between the coil loops and further spaced from the loop turn or twist area (both from the upper and lower coil turn areas). Also to facilitate the positioning of the magnets in the stator housing channel, a pin 142 may be mounted to the end of the magnet or to the end of the arm, which extends into a guide channel 144 formed in housing 140.

[00102] In this manner, when the magnet or magnets pass by the respective stator coil assembly or assemblies, the magnetic flux caused by the moving magnet induces electrical current to flow through the respective coils. Further, by positioning the coil on either side of the stator housing and, moreover connecting the coils in a manner to have their electrical flow additive, the turbine of the present invention may provide an increased electrical output for a given rotation of a shaft of a conventional turbine. Furthermore, because the turbines of the present invention do not need to use a gear box to translate the rotary motion of the turbine blade shaft into rotary motion that induces current flow, the various turbines of the present invention may generate electricity at lower wind speeds than conventional turbines that incorporate gears or gear boxes. Though it should be understood that a gear or gear box may be coupled to the shaft for example to drive a generator to provide an additional source of electrical generation.

[00103] Referring to FIG. 6, the numeral 210 generally designates another embodiment of a wind turbine of the present invention. Turbine 210, similar to turbines 10 and 110, includes a frame 212 and a turbine blade assembly 222 supported by frame 212 on a base 214. Frame 212 and base 214 may be also be formed from suitable metal components, including aluminum or stainless steel components, or in some applications composite materials. In the illustrated embodiment, base 214 comprises a movable base portion 214a and a frame mounting portion 214b, which is mounted to movable base portion 214a and to which frame 212 is mounted.

[00104] Frame 212 includes an annular cover 218, a post 219, brace frame members 220, and a turbine blade assembly 222. Brace frame members 220 mount cover 218 and turbine blade assembly 222 to post 219, which in turn mounts cover 218, frame members 220 and turbine blade assembly 222 to base 214. Cover 218 may be made from a metal sheet, such as an aluminum or stainless steel sheet, or a polymer, such as plastic, and also may be made from a composite material, again depending on the application.

[00105] In the illustrated embodiment, turbine blade assembly 222 includes a wheel 250 (FIG. 9) to which a plurality of turbine blades 226 are mounted. As best seen in FIG. 9, wheel 250 includes a central hub 250a and a plurality of radially extending spokes 252 that extend from hub 250a at their proximal ends and support a ring or rim 254 at their distal ends. As would be understood, the hub, the spokes, and the rim may also be formed from a metal material, such as aluminum or stainless steel. As best seen in FIG. 7, the spokes are offset at their connections to the hub but are mounted at spaced connections along a common annular path at the rim (see FIGS. 8 and 10) so that one set or group of

spokes lies on one conical surface and the other lies on another conical surface, similar to a bike wheel. Stated another way, a first group of the spokes extend from a first set of spaced connections at the hub to a second set of spaced connections arranged along an annular path on the rim. The second group of spokes extends from a third set of spaced connections at the hub to a fourth set of spaced connections along the same annular path as the second set of connections on the rim, where the first set of spaced connections is spaced from the third set of spaced connections along the hub's axis of rotation wherein the first group of spokes is offset from the second group of spokes at the hub but converge at the rim. As will be more fully described below, spokes 252 provide mounting surfaces for the turbine blades 226, which, in the illustrated embodiment, extend over a high percentage of the turbine's windward side, for example from about 50% to 70% of the windward side of the turbine, which is means the turbine has about a solidity from about 50% to 70%. As will be described, below the solidity of the turbine may be varied.

[00106] Referring again to FIG. 7, wheel 250 is supported by and journaled in brace frame members 220 by a shaft 250b, which extends through members 220 and is secured thereto by nuts 250c and optional washers 250d. Members 220 are then mounted to post 219 by brackets 260 and posts 262, which receive fasteners 264, such as bolts, that extend through the respective member 220, which is proximate post 219, and into post 219. Therefore, as noted above, the connection between the wheel and the supporting structure for the wheel is gearless. Though as noted a gear may be included.

[00107] In the illustrated embodiment, and as best seen in FIGS. 10 and 11, magnets 230 are mounted to wheel 250 and, more specifically, to rim 254 by a bracket 266, which is secured to rim 254 by a fastener or fasteners 268. Bracket 266 includes a mounting portion 270 that supports frame 272, which extends radially outward from mounting portion 270, and which supports magnet 230 therein. Magnets 230 are mounted such that they extend outwardly and lie (their major surfaces lie) in the same plane as the wheel and further between the plane defined by the windward side (side facing the incoming wind) of the blades and the plane defined by the leeward side (side facing the direction the wind is blowing) of the blades. In the illustrated embodiment, wheel 250 includes ten magnets 230, which are equally spaced around the wheel; however, it should be understood that more or fewer magnets may be used.

[00108] Referring to FIGS. 11 and 13, in the illustrated embodiment, stator coil assembly 232 is mounted to frame members 220 and is arranged around the outer perimeter of wheel 250. Further, in the illustrated embodiment, stator coil assembly 232 extends around only a portion of the circumference of the wheel and, further, is positioned at the top most blade position (12 o'clock). For example, stator coil assembly 232 may extend over an arcuate span in a range of about 30° to about 45°; though, it should be understood that it could be configured to extend over a greater range, including the full 360° circumference of the wind turbine. Stator coil assembly 232 includes support assembly 236, which is

mounted to frame brace member 220 and positioned in close proximity to ring 254. Further, as best seen in FIG. 12, support assembly 236 consists of a pair of brackets 236a and 236b, which are spaced apart and respectively mounted to frame members 220. Each bracket may comprise a generally L-shaped bracket and, further, include a pair of supports, for example in the form of cylindrical posts 276a that extend inwardly and support the stator coils 278a and 278b in a spaced relationship to thereby define a gap 280 between the respective stator coils. Stator coil assembly 232 is housed in cover 218 to thereby protect the stator coil assemblies and the respective magnets, as the magnets move though their circumferential path.

[00109] Referring to FIG. 12A, each pair of stator coils 278a and 278b are interconnected by a circuit 279, which may include a rectifier 279a to locally generate direct current (DC) from each individual coil. If rectifiers are not used then alternating current (AC) is produced. This can be rectified at a later state if needed. The electrical output can then be converted to a standard 12 volt DC to charge a small 12 volt DC car battery or a 120 volt alternating current standard output voltage for direct use.

[00110] Referring to FIGS. 14 and 14A, each blade 226 may be formed from a frame 282, such as a wire frame, and a flexible membrane 284, which may be formed from a fabric, such as nylon, polyester, or KEVLAR, or a thin sheet of a polymer material, such as plastic, which forms the web of the blade. Additionally, membrane 284 may be single-sided or two-sided—with one side mounted to one side of the frame, and the other side mounted to the other side of the frame. Frame 282 (FIG. 14A) has a generally isosceles trapezoid shape with two longitudinal sides 282a, 282b, which are aligned along radial axes of the wheel and are interconnected by transverse frame members 282c, 282d, and 282e. For example, frame 282 may be formed from a metal rod, such as aluminum or stainless steel or other rigid but light-weight materials. Membrane 284 is secured to frame 282, for example, by an adhesive, welds, stitching, or fasteners or the like.

[00111] Blades 226 then are mounted to the respective spokes 252 along their lengths by fasteners, such as snaps, ties, or the like, including clips formed from a spring material or an elastic material to allow the blades to deflect parallel to the wind, for example at high wind speeds. Further, as best seen in FIG. 8, the proximal end (end nearest hub 250a) of each blade may be secured to one spoke by a clip, while the other, wider distal end of the blade may be coupled to two spokes by two or more clips to support the distal end of the blade but not necessarily anchor the distal edge of the blade to the wheel's rim, thereby leaving a gap or gaps between the blade's distal edge and the rim of the wheel, which allows the blade to flex. Optionally, blades 226 are removable for repair and replacement.

[00112] When mounted to spokes 252, blades 226 are angled with respect to the central plane of the wheel. For example, blades 226 may be angled in a range, for example, from 2 degrees to 10 degrees including at about a 5 degree angle. At this angle it has been found that the turbine generates electricity at low speeds including as low as one mile per hour or less, including 0.3 miles per hour.

Depending on the particular materials used, it also has been found that the turbine will operate up to 40 or even up to 60 miles per hour, though it may be desirable to limit the speed of the turbine. At the higher speeds, as described in greater detail below, a microprocessor-based control system may be provided to change the direction of the turbine when the wind speed exceeds a desired maximum wind speed to thereby reduce the pressure on the blades. For example, the control system may turn the turbine into the wind to reduce the stress on the blades and on the wheel mounting components. In addition, as described below, the blades may be designed so that at higher speeds they reduce their surface area to reduce the solidity of the turbine and hence the speed of the turbine wheel.

[00113] Referring to FIGS. 15, 15A, and 15B, the numeral 1226 designates an alternate embodiment of the turbine blade. In the illustrated embodiment, blade 1226 is a molded blade and similar to the previous embodiment is mounted to a spoke 252 at one side and at its distal end to another spoke. As best seen in FIG. 15B, each blade 1226 is mounted to a respective spoke 252 along one edge along its full length by fasteners, such as snaps, ties, or the like, so that the blade is fully supported along its length (either at spaced intervals or continuously) along one edge by the wheel spoke and therefore limit deflection at the full range of wind operation of the wind turbine. However, the blade may be mounted using a clip that is made of elastic or a spring material to allow for blade deflection generally parallel to the wind, for example at high speeds. This may provide an automatic safety limit for the turbine wheel rotation.

[00114] For example, blade 1226 may be molded from a moldable material, such as a polymer, including a plastic, or a fabric, such as nylon or KEVLAR. Suitable polymers include glass-filled nylon, polyethylene, or a carbon fiber reinforced nylon or the like. In order to stiffen blade 1226, blade 1226 may be formed or provided with an outer perimeter rim 1228 and a web 1230 that extends between the outer rim. Rim 1228 may be formed from the same material as the web and simply have a greater thickness than the web to thereby in effect form a reinforcement frame, or rim 1228 may be formed from an insert material, for example a metal frame, such as an aluminum frame, that is molded with the blade to impart greater stiffness while reducing the weight of the blade, again thereby forming a frame for the web.

[00115] For example, rim 1228 may be formed, for example by molding, from one material which is then inserted into the mold where the material forming the web is then applied, for example, by injection molding. The rim may also comprise a wire frame similar to the previous embodiment, with the web molded over the frame. Alternately, the blade may be molded using two different materials using two-shot molding. Further, the web 1230 may be reinforced by ribs 1232 that extend across the face (either windward or leeward side) of the blade and optionally between two opposed sides of the rim 1228. Ribs 1232 may have a greater thickness than web 1230 and may have the same, lesser or greater thickness as rim 1228. Again the ribs may be pre-formed and then inset into the mold or may be formed with the web, for example during molding, including using two shot molding.

[00116] For a constant wind speed and wheel rotational speed, the blade root, nearest the wheel hub, experiences the slowest radial velocity. Whereas the blade tip, nearest the wheel rim would experience the maximum radial velocity. As best seen in FIGS. 15A and 15B, the blade angle of attack may thus be varied along its length to accommodate efficient aerodynamic energy conversion to mechanical rotation of the wheel. For example, in the illustrated embodiment, the attack angle of blade 1226 may decrease along its length, from its blade root (proximal end) 1226a to its blade tip (distal end) 1226b. Therefore, the blade is asymmetrical. For example, the blade root 1226a may have a very steep attack angle, for example, in a range of 40 degrees to 50 degrees, or in a range of 42 degrees to 48 degrees or approximately 45 degrees. The attack angle at the tip may range from 0 degrees to 10 degrees, or in a range of 2 degrees to 5 degrees or approximately 3 degrees. This is achieved by the asymmetrical shape of the blade, which is concave on its windward side and convex on its leeward side. Given that the blade is formed form a thin web (except for its perimeter rim and reinforcing intermediate ribs), the blade's asymmetry can be formed from twisting the blade during its formation from its root end (end nearest to the hub) to its distal end (tip). Therefore, as would be understood the wind facing surface of each blade is not perpendicular to the incoming wind. This design approach increases the lift coefficient and minimizes the drag forces along the blade length at various wind speeds.

[00117] Referring to FIGS. 16-18, the numeral 226' designates an alternate embodiment of the blades in which the blades are configured to reduce the solidity of the turbine wheel. As noted above solidity refers to the amount of surface area defined by the circumference of the blade tips covered by the blades. For example, a 100% solidity would mean that the blades cover the entire surface. For a 30% solidity, the blades cover 30% of the area. As will be more fully described below, each blade 226' may be adapted to self-adjust the solidity in response to increased wind speeds.

[00118] Referring again to FIGS. 16-19, blade 226' includes a frame 282 similar to blade 226 and a membrane 284', which is similarly formed from a flexible material, such as a fabric or thin sheet of flexible material or the like. In the illustrated embodiment, membrane 284' comprises a primary, fixed partial membrane and extends from the inward transverse member 282c of frame 282 to the medial transverse member 282d and, therefore, only covers a portion of the frame 282. In order to vary the solidity, turbine blades 226' are configured to take advantage of the centrifugal forces acting on the turbine blade so that as the wind speed increases the solidity of the turbine blade assembly decreases.

[00119] Referring again to FIGS. 17-19, turbine blade 226' includes a second membrane 284a'. Membrane 284a' is mounted about frame 282 and extends between intermediate transverse frame member 282d and outermost transverse frame member 282e. Further, membrane 284a' is mounted such that its inwardly facing end 286a' is secured to a movable member 288' in the form of a plate 290'. Plate 290' includes with a pair of elongate guide openings 292', which allow the plate 290' to be mounted to side frame members 282a and 282b of frame 282 and slide along the frame. In this

manner, the inwardly facing end 286a' of membrane 284a' may move relative to frame 282 and, further, compress toward its outer end 286b' to allow a gap to form between membranes 284a' and 284' to thereby reduce the solidity of the respective turbine blade.

[00120] To control the bending or folding of membrane 284a', a pair of springs are provided 294'. Springs 294' are coupled on one end to outermost transverse frame member 282e and, further, are extended along the respective side frame members 282a and 282b and coupled at their distal ends to transverse member 288'. Further, when mounted springs 294' are compressed so that the respective springs bias and urge transverse member 288' toward transverse member 282d of frame 282 to thereby maintain membrane 284a' in its extended state wherein the lower end 286a' abuts the outer end 286' of membrane 284'. As the wind speed increases and the centrifugal forces on the respective membranes increase, transverse membrane 288' will compress springs 294' and thereby allow membrane 284a' to compress, for example by folding. For example, member 284a' may be pleated so that membrane compresses in a controlled fashion.

[00121] It should be understood that the ratio of the secondary membrane 284' size relative to membrane 284' size may be varied to vary the change in solidity of the blade. Furthermore, the stiffness of the respective springs may be varied to adjust the responsiveness of the turbine blade. Therefore, as described above, the blades of the turbine may be adapted to reduce its solidity based on the wind speed. Consequently, as the blades rotate, the blades may self open based on the rpm.

[00122] Another option is to provide membranes formed from a material whose porosity increases with air pressure to thereby decrease its solidity.

[00123] Referring to FIG. 20, the numeral 310 designates another embodiment of the wind turbine of the present invention. Similar to the previous embodiments, wind turbine 310 includes a frame 312, a turbine blade assembly 322 supported by frame 312 on a post 319, which supports the frame on a base 314. Similar to the second embodiment, base 314 comprises a fixed base portion 314a but supports post 319 for rotational motion about fixed base portion 314a. As best seen in FIG. 20, post 319 is mounted in base 314 by bearings 314b and, further, may be driven by a motor 314c housed in base 314, which is controlled by a control system, which may be any of the control systems described below or another type of control system. Further, in the illustrated embodiment, fixed base portion 314a may include a base plate 314e and a plurality of support legs 314d which are pivotally mounted to base plate 314e to allow the height and footprint of the base 314a to be adjusted as needed. Legs 314d may be interconnected and reinforced by brace members 314f. Similar to the previous embodiments, the connection between the turbine blade assembly and the supporting structure for the wheel is gearless.

[00124] Turbine blade assembly 322 may be of similar construction to turbine blade 222 and, therefore, reference is made to the previous embodiment for details of the wheel 250 and blades 226 mounted to wheel 250. However, in the illustrated embodiment, magnets 330 are mounted to wheel 250 with a perpendicular orientation to the rotational plane of wheel 250 so that their major surfaces

extend in a generally horizontal direction. Magnets 330 extend into a stator coil assembly 332, which has a similar construction to stator assembly 232 with exception of its orientation, which is rotated 90 degrees relative to the orientation of stator coil assembly 232 shown in the previous embodiment. In this manner, when wheel 350 experiences some wobble, the magnets will move generally parallel to the coils in the stator assembly and will generally maintain their gaps with the respective coils.

[00125] Referring to FIG. 20, stator coil assembly 332 is similarly mounted at the twelve-o'clock position and, further, may extend over an arcuate portion of the circumference of wheel 250 in a range of about 30 degrees to 45 degrees (or may extend around the full circumference of the wheel) and is mounted to orient the gap 380 between the respective stator coils 378a and 378b in a generally horizontal arrangement to thereby receive magnets 330 in their respective horizontal orientation as shown in FIGS. 20 and 21. Magnets 330 are also mounted to rim 254 of wheel 250 by brackets 366 and pins 366a, which support magnets 330 as noted above, but in a perpendicular arrangement relative to the rotational plane of wheel 250 (FIG. 22). Similar to the previous embodiment, shaft 250b of wheel 250 is rotationally mounted to post 319 by a bracket 260' and, further, by an additional support arm 319a, which is mounted to post 319 by a bracket 319b, as best seen in FIG. 21. In this manner, both ends of the rotational shaft 250b are supported. In the illustrated embodiment, bracket 260' comprises a flanged channel-shape member that mounts to post 319 by fasteners that extend through its flanges.

[00126] Referring to FIGS. 26 and 27, the numeral 410 generally designates another embodiment of the wind turbine assembly of the present invention. Similar to the previous embodiments, wind turbine 410 includes a frame 412 that supports a wind turbine blade assembly 422 on a base 414. Wind turbine blade assembly 422 includes a wheel 450 similar to wheel 250 to which turbine blades 426 are mounted. For further details of wheel 450 and turbine blades 426 reference is made to the previous embodiments. Frame 412 includes an annular member 418, which supports a plurality of stators coils 432 arranged around the circumference of wheel 450, which have a channel-shaped arrangement, as described in reference to the previous embodiments, to receive magnets mounted to the rim 454 of wheel 450. In this manner, as wheel 450 spins around its axis 450a, the magnets 430 mounted to rim 454 will induce electrical current flow in the stator coils similar to turbine 210.

[00127] Frame 412 is supported on base 414 by a post 419 and a semicircular frame member 414a, which mounts frame 412 to post 419. Frame member 414a is secured, for example, by fasteners 414b to medial transverse frame members 420a and 420b of frame 412. Transverse frame members 420a and 420b are joined at their opposed ends by transverse frame members 421a and 421b, which provide a mounting surface for semicircular frame member 414a. Shaft 450b of wheel 450 is then supported in transverse frame members 420a and 420b, for example in bushings. Again as noted above, the components forming the frame and the base may be metal, polymeric or composite components.

[00128] Optionally, turbine 410 includes an auxiliary set of turbine blades 526, which are mounted on blade arms 528, which are rotatably coupled to shaft 450b of wheel 450. In this manner, when wheel 450 rotates about its rotational axis 450a, blades 526 will rotate simultaneously with wheel 450. Blades 526, therefore, provide additional surface areas to increase the rotational speed of the wheel 450.

[00129] Optionally, post 419 may be rotatably mounted to base 415 and, further, rotated about base 414 by the wind. For example, a wind vane 480 may be mounted to frame 412 so that the wind will adjust the position of turbine 410.

[00130] Referring to FIG. 28, the numeral 610 generally designates another embodiment of the wind turbine of the present invention. Turbine 610 includes wind turbine wheel 250 with a plurality of blades 626 mounted to wheel 250, a stator coil assembly 322, a base 614, and a cover 650. Base 614 is similar to base 214 of turbine 210, which allows the wind turbine wheel 250 along with its blades to change direction in response to the wind speed and direction, as described in reference to the previous embodiments.

[00131] In the illustrated embodiment, blades 626 are molded from a plastic, such as described in reference to blades 1226, and are similarly mounted to the spokes of the wheel by fasteners, such as clips. Also, similar to blades 1226, and as best seen in FIG. 28D, blades 626 may be mounted to the spokes using clips that allow for deflection of the blades in response to the wind speed exceeding a preselected threshold. The longitudinal edge of each blade may be secured by multiple clips to one spoke, while the other longitudinal edge may be unrestrained but with the distal end of the blade (at the end of the unrestrained longitudinal edge) may be mounted by a clip to an adjacent spoke, which accommodates the asymmetrical shape of the blade. Thus, each of the blades' distal edges (see e.g. FIG. 28D) are therefore connected to the wheel by at least two clips (one at the end of the restrained longitudinal edge and the other at the unrestrained longitudinal edge) but decoupled from the rim. In this a manner, there is a gap between the distal edge of each blade and the rim of the wheel, leaving the blades with several degrees of freedom at their distal ends (as well as along their unrestrained longitudinal edges) so that the blades are allowed to flex or bend under high wind speeds. For further details of the wheel and the blades, reference is made to the previous embodiment.

[00132] Like turbine 310, however, turbine 610 mounts its magnets so that they extend outwardly from wheel 250 in a direction angled to the plane of rotation of wheel 250 (see FIGS. 28A, 29, 29A, and 29B) and into stator assembly 622 (FIGS. 28A and 28B). Stator assembly 622 is of similar construction to stator assembly 322 and is oriented so that its channel is in a horizontal plane to receive the generally horizontally arranged magnets.

[00133] Similar to the previous embodiments, wheel 250 is mounted to a post 619 (FIG. 28D) on shaft 250b by a bracket 660 (similar to bracket 260'). Mounted to post 619 is a plurality of transverse frame members or rods 620a, 620b, 620c, which together mount stator assembly 622 to post 619.

Optionally, transverse support member 660a may be braced by diagonal support members 620d and 620e. Post 619 and members 620a, 620b, 620c, 620d, and 620e may all be formed from metal components, including aluminum or stainless steel members, including aluminum or stainless steel tubular members.

[00134] As best seen in FIG. 28B, stator assembly 622 includes a plurality of stator sub-assemblies 622a that are mounted on a non-conductive plate 622b, which mounts stator assembly 622 to transverse support members 620a, 620b, and 620c with fasteners (see e.g. FIG. 28B).

[00135] Similarly, the leeward side (the side facing the direction in which the wind is blowing) of cover 650 may be mounted to the transverse support members 660a, 660b, and 660c by fasteners or brackets (not shown). The windward side of cover 650 is mounted to a frame 620, which supports the opposed end of shaft 250b in a central frame member 620f. Extending outwardly from central frame member 620f, which in the illustrated embodiment is in the form of a block, are radially extending frame members 620g, which in turn are coupled to cover 650. In this manner, post 619 supports wheel 250, stator assembly 322, and cover 650.

[00136] Referring again to FIG. 28D, post 619 is mounted to the upwardly extending post 614a of base 614 to provide a rotatable mount for wheel 250. Post 619 is rotatably mounted to post 614a by a bracket 619a and bushing (not shown) and further is optionally driven about post 614a by a driver 614c, which is driven by a controller to change the orientation of the wind turbine wheel, as described in the detailed description of the controls systems below.

[00137] Referring to FIG. 28D, the inner end of each blade may be coupled to the inner end of its opposed blade, for example, by a rod, such as a metal rod, or wire member 600. Member 600 includes loop ends 600a for extending through openings formed in each respective blade and thereby engaging each respective blade. It should be understood that other suitable mounting methods may be used. Members 600 therefore tie opposed blades together to balance the centrifugal forces generated at the blades and reduce the stresses on the shaft. It should be understood that in any of the wind turbine described above, the blades on opposed sides from the hub may be tied together, for example, by the tie support, such as rod or wire member 600(see e.g. FIG. 6), which is coupled on one end to one blade and then coupled at its opposite end to the other, opposing blade.

[00138] Further, because blades 226, 1226, 226', 426 are each configured so that their outer ends have a greater expanse than at their inner ends, the stresses at the rotational shaft may be further reduced. When this is combined with balancing of the centrifugal forces by way of members 600, the stress on the shafts of the respective turbines due to the centrifugal forces normally generated at a wind turbines blades can be drastically reduced, if not effectively eliminated.

[00139] Optionally, the tie supports may be formed from a material that can extend or stretch to allow the blades to compress as described above in reference to the blades with the bifurcated webs, while still balancing the centrifugal forces. For example, the tie supports may be made from an

elastomeric material or incorporated a spring, such as a spring integrated into or formed in the rod or wire, for example.

[00140] In addition to balancing the centrifugal forces on the blades, wind turbine 610 may also balance the centrifugal forces on the magnets. For example, in the embodiment where the magnets are orthogonally oriented in relation to the rotational plane of the wheel, additional rods 602 (FIGS. 22 and 24) may be extended through the wheel, with their distal ends, e.g. threaded distal ends, anchored in the magnet mounting brackets of opposed magnets (see FIG. 24) by for example nuts. Alternatively, the ends of the rods may be welded to the respective brackets or formed with the respective brackets.

[00141] As best understood from FIG. 29, each of the respective wind turbines may incorporate a guide that provides lateral support to the wheel or frame to reduce vibration or wobbling, to thereby reduce the wear and tear on the components. In the illustrated embodiments, each wheel may include two or more bearings 630 in the form of rollers 632, such as polymeric rollers, that are mounted to the wheel or frame for bearing on the stator housing. In the illustrated embodiment (in which magnets are mounted perpendicular to the rotational plane of the wheel) rollers 632 are mounted to the rim of the wheel by a bracket 634 and are mounted so that they extend inwardly for bearing on the outer annular facing of the stator housing. In this manner, as the wheel is rotated about its rotational axis on its shaft, the wheel is provided at least some lateral support at its outer perimeter, which may be particularly advantageous when the wind speed increases.

[00142] Referring to FIGS. 29A and 29B, another embodiment of a guide 630' is illustrated. Guide 630' is formed from a plate 632, such as a metal or plastic plate. Plate 632 is also mounted to the rim of the wheel, for example, by fasteners or welds, and may be located adjacent each magnet mounting bracket and further such that they extend over the tie rods 602 that connect the opposed sets of magnet mounting brackets together. In this manner, plates 632 assume an arcuate or arched cross-section to provide a cam guide surface to help counteract any wobble in the wheels and help guide and maintain the turbine wheels in their rotational plane. Additional plates may also be located between the magnet locations.

[00143] Additionally, as noted in each of the wind turbines described herein, the stator assemblies may be enclosed in a cover. Referring to FIG. 30, cover 650, which may be mounted to any of the frames of the wind turbines described above, is adapted to converge the flow of air into the turbine blades and thereby further reduce the wind speed needed to operate the various wind turbines and also increase the efficiency of the wind turbine.

[00144] As best seen in FIGS. 30, 30A, and 30B, cover 650 may be formed from several arcuate members 652, 654, 656, and 658 that are connected together to form an annular cover. Cover 650 may be formed from metal or polymeric components, such as aluminum or stainless steel or plastic, and also optionally composite materials. Although described as being formed from several members, the cover may also be formed a single member. Members 652, 654, 656, and 658 are fastened

together at their overlapping respective ends, for example, by fasteners. Referring to FIGS. 30A and 30B, one end of each member may include a mounting flange 652a, 654a which is overlapped by the other end of the adjacent member and secured thereto by fasteners or welds or the like.

[00145] Referring to FIG. 30C, each member 652, 654, 656, and 658 comprises a thin walled member with a cross-sectional profile that forms an annular diverging surface 650a for facing the wind (generally designated by the arrow in FIG. 30C). In addition, each member 652, 654, 656, and 658 includes an outer annular arcuate surface 650b which directs the outwardly redirected air flow across and around the cover. Inwardly of diverging surface 650a is an angled annular surface 650c, which directs the inwardly directed air flow into the blades to thereby converge the flow of air into the turbine blades.

[00146] Referring again to FIG. 28, optionally, any of the wind turbines of the present invention may incorporate an extension or wind concentrator, for example, to the cover that increases the windward facing side of the wind turbine and, which is adapted to increase the wind input into the wind turbine. While reference is made to turbine 610, it should be understood that the extension may be formed or mounted on any of the previous embodiments.

[00147] As best seen in FIGS. 28 and 28C, extension 670 has a generally frustoconical shape and is mounted to cover 650 at the cover's outer perimeter by a plurality of fasteners 670a to provide a conical surface extending radially outward from the tips of the turbine blades. Extension 670 may be formed from a flexible sheet material, such as plastic, a fabric (such as shown in FIG. 31), or the like, so that the extension is lightweight and, moreover, relatively easy to mount and further remove for easy transport. When formed from a flexible sheet, the sheet may be maintained in its generally frustoconical shape by support arms 670b which are mounted to cover 650 at spaced locations around the circumference of cover 650 by fasteners 670a.

[00148] As best seen in FIG. 28C, arms 670b optionally extend into pockets 670c formed or provided in the sheet and/or may be secured to the sheet for example by fasteners, such as snaps or the like, so that arms 670b are optionally removably mounted to the sheet. In this manner, the extension may be fully collapsible once removed and disassembled.

[00149] Extension 670 is angled so that extension 670 increases the collection surface of the wind turbine and, further, so that it directs the wind into the turbine wheel that would otherwise pass by the wind turbine. Further, it also helps to reduce the pressure at the blades, despite the high solidity provided by the blades. For example, extension 670 is angled outwardly from the cover as measured from the rotational axis of the turbine wheel at an angle in a range of 20° to 75°, more typically in a range of about 30° to 60°, and optionally at about 60° . When the turbine has a solidity of 30% or higher, the dynamic pressure at the blades tends to increase. Therefore, the wind speed tends to decrease. With the design of the cover and extension described above, the wind speed is increased as it approaches the wind turbine wheel, which reduces the pressure even with higher solidity. Further, at

low wind speeds, the flow is accelerated in both directions (into the wind turbine wheel and around the outside of the cover). When the wind is accelerated into the wind turbine wheel, the pressure in the wind turbine wheel drops, which allows more air to be drawn into the wheel.

[00150] As noted above, the extension may be formed from a fabric, such as nylon coated polyester, such as shown in FIG. 31. Extender 670' is formed from a fabric and further includes additional extended portions 675 and 677, which may be formed from separate panels 675a and 677a that are mounted to extension 670' or are simply extended portions of the sheet forming the extension. Panels 675a and 677a may be formed from the same flexible sheet material as extender 670' and have a perimeter frame 675b and 677b, respectively, to support the flexible sheet material in its generally rectangular or trapezoidal shape and further provide a mounting surface for mounting the respective panels to the ends of arms 670b'. Panels 675a and 675b are angled rearward of the outer perimeter 670c' of extension 670' in the leeward direction (in the direction that the wind is flowing) to provide left and right wind force stability. For example, panels 675a and 677a may extend rearward at an angle as measured from the rotational axis of the turbine wheel in a range of 20° to 75°, typically in a range of 30° to 60°, and more typically at about 60° so that together, each panel forms an apex with the extension over a discrete angular segment of the extender, which again helps separate the wind. The panels may be flat or may be arcuate with a similar radius of curvature to the extension at their point of attachment, for example.

[00151] Referring to FIG. 32, any one of the wind turbines of the present invention 10, 110, 210, 310, 410, or 610 may be mounted to a structure, such as a house or garage or office building. For example, the wind turbines may be mounted to, for example a roof of the house and may provide power to the electrical system of the house, as described more fully in the referenced copending application.

[00152] Referring to FIG. 33, a graph of a Class 4 wind Rayleigh distribution is provided, which illustrates the cut-in wind speed for most typical turbines, which is typically around 8 miles per hour. Further, the graph illustrates that the plate power, in other words the maximum capacity of the wind turbine of most conventional turbines, typically occurs at about 28 miles per hour. Further, most conventional wind turbines have a cut-off wind speed of about 34 to 35 miles per hour to reduce the chances of the turbine lift-offing and becoming airborn. In contrast, the present invention provides a wind turbine, which may operate at lower speeds and, further, which may have a cut-in speed of less then 8 miles per hour, less than 6 miles per hour, less than 4 mph, and optionally less than 1 mph and even as low as 0.3 miles per hour. In order to accommodate higher wind speeds, as described above, the turbines of the present inventions may have their respective turbine blades configured to self-adjust or self-configure to reduce the solidity of the turbine at higher wind speeds to thereby eliminate the chance of the turbine lifting off when subject to high wind speeds. In cases where the solidity of the turbine blades is fixed, the control system may slow and/or adjust the orientation of the wind turbine. For example, at wind speeds of 40 mph the control system optionally shunts the turbine with high

powered resistance to stop the turbine from going too fast—and further rotates the wind turbine so that it is, for example, parallel to wind. As described in the copending application, a microprocessor-based control system may be provided to control the direction of the turbine to reduce the stress on the wind turbine or to optimize the direction of the turbine so that the angle of receipt of the wind can be maintained at for example 120 degrees relative to the face of the turbine. Furthermore, with the present construction, the turbine may be oriented to receive wind from its front facing direction as well as its rearward direction so that it is bidirectional.

[00153] While several forms of the invention have been shown and described, other forms will now be apparent to those skilled in the art. For example, optionally, to increase power output, in addition to providing coils on both sides of the magnets and further making their inductive current flow additive, the magnets size may be increased. For example, the thickness of the magnets may be increased from ½ inch, as noted, to 0.7 inches, to 0.8 inches, or 1 inch thick. Further, to increase efficiency, the gap between the magnets can be reduced. For example, the total gap (for example, in the case of the horizontal magnets, the gap above and the gap below the magnet) may be in a range of 50/1000 inch to 400/1000 inch. When the magnets are arranged in a horizontal arrangement and therefore extend in the direction of the wheel wobble, any wobbling motion will not significantly impact the gaps between the magnets and the stator assembly. Further, as noted above, this wobbling motion may be reduced with the addition of the rollers or cover plates described above. It also should be understood than any feature or features of one turbine may be incorporated in the other turbines described herein, and further may be may incorporated in other conventional turbines.

[00154] An electrical generation system 720 according to one embodiment of the present invention is depicted in FIG. 34. Electrical generation system 720, as depicted, includes a wind turbine 722 and a control system 724. Wind turbine 722, as will be discussed in greater detail below, is adapted to generate an electrical voltage in response to the wind causing a plurality of fan blades 726 on turbine 722 to rotate. Stated alternatively, wind turbine 722 generates electrical energy from the wind. Wind turbine 722 may be designed in accordance with any of the wind turbine embodiments described previously (e.g. it may be the same as any of wind turbines 10, 110, 210, 310, 410, or 510) or it may be a conventional wind turbine, or it may be designed in other manners. Control system 724, as will also be discussed in greater detail below, is adapted to control the orientation of wind turbine 722 so that it faces the direction of the wind at a suitable angle for optimizing the electrical energy generated while also protecting wind turbine 722 from excessive wind speeds. Control system 724 is also adapted to process the generated electricity in a useful manner, such as by charging one or more batteries when sufficient electricity is being generated, or by transferring the electrical energy directly to a residential or commercial load when the load demand equals or exceeds the electrical energy currently being produced by turbine 722.

[00155] In the embodiments depicted in FIGS. 34-36, wind turbine 722 is constructed such that the fan blades 726 have a relatively high solidity. That is, the size and/or number of the blades 726 is such that the circular area defined by the rotation of the blades has a relatively small amount of area that is not occupied by the blades. Stated in yet another manner, there is a relatively small amount of space between the blades 726. In some embodiments, the amount of space between the blades may be less than 50% of the total area of the circle defined by the rotation of the blades 726. In other embodiments, the space may be less. In still other embodiments, the total area of the blades 726 may comprise 70% or more of the total area of the circle defined by the rotation of the blades 726.

[00156] The purpose of the relatively high solidity of blades 726 of wind turbine 722 is to allow wind turbine 722 to start rotating at relatively small wind speeds (i.e. to have a small cut-in wind speed), such as speeds of 1 or 2 miles an hour, although speeds even less than this may also be accommodated in certain configurations of turbine 722. It will be understood by those skilled in the art, however, that turbine 722 can be varied substantially from that depicted herein. For example, embodiments of electrical generation system 720 may be utilized with a wind turbine 722 that does not have a relatively high solidity. Further, electrical generation system 720 may comprise a wind turbine 722 that is substantially different in physical construction from wind turbine 722 pictured in FIGS. 34-36.

[00157] FIG. 35 depicts a side, elevational view of one manner in which wind turbine 722 may be constructed. Other constructions are, of course, possible. As shown in FIG. 35, wind turbine 722 includes a stand or mount 728 (FIG. 34) which supports wind turbine 722. Stand 728 may take on a variety of different configurations, such as that of stand 728' shown in FIG. 35, as well as other variations. Supported on mount 728 or 728' is a vertical shaft 730. A bearing bracket 732 is secured to shaft 730 by any suitable means. Bearing bracket 732 supports, either completely or partially, a horizontally oriented axle 734 about which fan blades 726 rotate. Fan blades 726, which are not shown in FIG. 35, are secured to a frame 736 that is rotatably mounted to axle 734. In one embodiment, frame 736 and axle 734 may comprise a conventional bicycle wheel to which fan blades 726 are suitably mounted. The use of a conventional bicycle wheel helps reduce manufacturing costs by incorporating pre-existing, mass-produced components. In other embodiments, frame 736 and axle 734 may be custom-manufactured, or constructed using other materials and/or components other than conventional bicycle wheels.

[00158] In the embodiment depicted in FIG. 35, a plurality of magnets 738 are mounted generally around a periphery of frame 736. Magnets 738 are positioned such that the magnetic flux of the magnets intersects with a plurality of stator coils 740 similarly positioned around the periphery of frame 736. As is well known from Faraday's law of induction, the movement of the magnetic flux from magnets 738 relative to the stationary stator coils 740 will induce a voltage inside of the stator coils 740. The stator coils 740 are physically arranged, and electrically coupled together, in such a manner that

the voltages created inside each of them are added together, thereby causing an electrical current to flow in a wire or cable 742 that is fed into control system 724.

[00159] In other embodiments, the magnets 738 and stator coils 740 may be positioned inside of a gearbox located generally near the axle 734 about which blades 726 rotate. Such a gearbox may amplify the rotational speed of the magnets relative to the rotational speed of the blades 726 in a known manner to thereby increase the rate of change of magnetic flux intersecting stator coils 740, which, in turn, increases the voltage generated by wind turbine 722. Still other physical arrangements of the magnets 738 and stators are possible, such as those described previously, as well as other arrangements. Control system 724 may be used in conjunction with the wind turbines described herein, or it may be used, in some embodiments, with any type of wind turbine.

[00160] Wind turbine 722 further includes a motor 744 positioned adjacent a bottom end of vertical shaft 730 (FIG. 35). Motor 744 may be enclosed within a housing 746 adapted to shield motor 744 from the effects of the weather. Motor 744 is configured to interact with vertical shaft 730 such that operation of motor 744 will cause shaft 730 to rotate about its vertical axis. The rotation of vertical shaft 730 causes the orientation of wind turbine 722 to change. That is, the direction which wind turbine 722 faces may be altered by activating motor 744. Motor 744 may therefore be used to turn wind turbine 722 such that it faces into the wind, or is positioned at a particular angle with respect to the direction of the wind, as will be discussed in greater detail below.

[00161] The operation of motor 744 is controlled by control system 724. Control system 724 may transmit motor control commands to motor 744 by way of a wired connection (not shown) or a wireless connection. When using a wireless connection, motor 744 may include an antenna 748 (FIG. 35) that receives the commands from control system 724 and implements them accordingly. Such wireless transmission of commands to motor 744, as well as the transmission of status information from motor 744 to control system 724, may be carried out using any suitable transmission protocol or standard, such as, but not limited to, Bluetooth (IEEE 802.15.1 standards), WiFi (IEEE 802.11 standards), and other wireless technologies. In addition to receiving commands from control system 724, motor 744 may also transmit status information to control system 724, such as the angular orientation of wind turbine 722 (e.g. whether facing north, south, east, west, etc), as well as other information.

[00162] In at least one embodiment, turbine 722 includes suitable rectifiers that convert the AC voltage generated at the turbine 722 to DC voltage prior to transmitting the voltage to control system 724. In other embodiments, the AC voltage could be rectified by control system 724, or used without rectification.

[00163] An anemometer 750 may be positioned adjacent wind turbine 722 (FIG. 35) in order to measure wind speed and/or wind direction. When utilized, anemometer 750 is configured to generate electronic readings of the wind speed and/or wind direction and to forward those readings to control system 724 in any suitable manner. The transmission of these readings to control system 724 may be

done wirelessly via a separate transmitter attached to, or electrically coupled to, anemometer 750. Alternatively, anemometer 750 may feed its readings to the transmitter utilized by motor 744. In other embodiments, a wired connection may be used to send anemometer 750's readings to control system 724. Such wired connections may utilize a separate wire between anemometer 750 and control system 724, or they may be transmitted via power line 742 through any suitable coding technique that allows control system 724 to separate the anemometer's readings from the electrical power generated by wind turbine 722 that is transmitted to control system 724 over wire 742.

[00164] In still other embodiments, the wind speed may be measured by suitable sensors attached directly to wind turbine 722, rather than through the use of a separate anemometer. Or, in still other embodiments, the wind speed may be determined by measuring the amount of electrical current transmitted through line 742 in combination with a known wind speed profile of wind turbine 722 that identifies the amount of power generated by turbine 722 over a range of speeds. Such a profile may be stored in a memory of control system 724.

[00165] Electrical generation system 720 may be used to either supply the entire electrical needs of a residence, such as a residence 752 (FIG. 36), or it may be used to supplement the electrical power supplied to a residence 752 from a utility company. As will be described in more detail below, generation system 720 may be easily configured to supply electrical energy to one or more circuits within a residence by integrating the system 720 into the pre-exiting breaker box or distribution panel within the residence. Alternatively, electrical generation system 720 may be used to supply electrical power to businesses, or any other consumers of electrical power. Multiple electrical generation systems 720 may also be combined together to increase the supply of electrical energy. Wind turbine generation system 720, in some embodiments, has a physical footprint enabling it to be mounted onto a residence 752 (FIG. 36), or to be conveniently positioned within a residential yard without occupying an undue amount of space.

[00166] A generalized schematic diagram of one embodiment of control system 724 is illustrated in FIG. 37. A more detailed diagram of the embodiment shown in FIG. 37 is illustrated in FIG. 38. FIG. 39 shows a more detailed diagram of one embodiment of a charge controller 754 that may be used with control system 724. It will be understood by those skilled in the art that the details of control system 724 may be varied substantially from the embodiments depicted herein.

[00167] Control system 724, in the embodiment shown in FIGS. 37 and 38, includes charge controller 754, an inverter 756, one or more batteries 758, and suitable electrical wires/cables for connecting control system 724 to wind turbine 722 and one or more distribution panels 760. The one or more distribution panels 760 may be conventional distribution panels 760 found within a home or residence and used to distribute the utility-supplied electrical power amongst the various circuits that supply electricity throughout the residence or business. Such distribution panels typically include fuses or circuit breakers for each of the electrical circuits within the residence or business that supply

electricity to electrical outlets 790 positioned in different areas of the residence or business. Control system 724 can be easily coupled to such a distribution panel to enable one or more of the circuits of the distribution panel to receive its electricity from electrical generation system 720. Thus, for example, if the home or business includes a separate circuit for a hot tub, or a water heater, or a particular room or area of the home or business, electrical generation system 720 can be coupled to the distribution panel 760 such that the electricity for the water heater, or room, or area, can be supplied by system 720, rather than the utility company. Of course, as will be explained in greater detail below, electrical system 720 is constructed, in at least one embodiment, such that, in the absence of sufficient wind power and/or the drainage of batteries 758, system 720 will automatically switch to supplying the desired electrical power from the utility company. In this manner, electricity is supplied to the connected circuits even in no-wind conditions and when battery 758 is drained.

[00168] Electrical generation system 720 is also configured such that, upon an interruption in utility-supplied electrical energy to the home or business, system 720 will automatically switch to a back-up mode in which it will supply electrical energy to the home or business via one or more batteries 758 (in no-wind or insufficient-wind situations) or via wind turbine 722. In this manner, system 720 acts as a sort of emergency generator that automatically kicks in when an interruption in utility-supplied power is detected, thereby providing continuous electrical service to the home or residence and thereby also eliminating the requirement of a person manually starting or otherwise manually activating a gasoline, or other fuel-powered, emergency generator. After such an interruption in utility-supplied electrical power, system 720 will continue to supply electricity to the home or business for as long as it is able until the utility-supplied electricity returns. Once the utility-generated power returns, system 720 will-recharge the battery or batteries 758, either through power generated from turbine 722 or through utility-supplied power, or a combination of both.

[00169] As illustrated in FIGS. 37 and 38, turbine charge controller 754 and inverter 756 may be housed within an enclosure 762 that may be mounted to a wall, or other suitable structure, within the home or other facility receiving electrical power from turbine 722. Enclosure 762 may include a door 764 that opens and closes to allow access to the interior of enclosure 762 where charge controller 754 and inverter 756 are located. Door 764 may include a lock 766 to prevent unauthorized access to enclosure 762.

[00170] As shown in FIG. 38, cable 742 may comprise a plurality of individual wires, such as a positive or "hot" wire 742a, a ground wire 742b, and an earth wire 742c. Hot wire 742a carries the direct current generated by wind turbine 722 to control system 724. Hot wire 742a feeds into enclosure 762 and passes through a fuse 768 prior to being fed into charge controller 754. Ground and earth wires 742b and 742c are attached to suitable connectors 770 inside, or adjacent, enclosure 762. As will be discussed in more detail below, charge controller 754 monitors the voltage and current of hot wire 742a and makes various adjustments and control decisions based upon these voltage and current

levels, as well as based upon other conditions, such as the state of charge of batteries 758 and/or the load electrically coupled to control system 724.

[00171] Charge controller 754 is also in communication with motor 744 and anemometer 750. Such communication may occur by any of the methods discussed previously. As shown in FIG. 38, charge controller 754 is in communication with an antenna 772 that detects the wireless signals transmitted by motor 744 (through antenna 748) and/or anemometer 750, which may transmit wireless signals through the same antenna 748 or some other antenna. Alternatively, charge controller 754 may receive the wind speed and wind direction information from anemometer 750 and the orientation information from motor 744 through other communication channels. Charge controller 754 uses the wind speed and wind direction signals, in combination with the measurements of voltage and current in hot wire 742a, to control the charging of batteries 758, the movement of motor 744, the state of a transfer switch 774, the operation of one or more DC-DC converters internal to controller 754 (such as buck converters, or other suitable converters, as discussed more below), and the operation of inverter 756.

[00172] In general, charge controller 754 converts the voltage of the incoming DC electrical current from wind turbine 722 (received via hot wire 742a) to a more suitable voltage level that may be applied to either or both of inverter 756 and/or battery 758. Inverter 756, in turn, converts the DC current it receives from either battery 758 and/or inverter 756, or both, into an AC current having a voltage level and frequency suitable for use in the home or business to which system 720 is supplying power. Thus, for North American homes or businesses, inverter 756 outputs a 120 volt, 60 Hertz (Hz) alternating current signal. For European homes or businesses, inverter 756 may be configured to output 230 volts AC at a frequency of approximately 50 Hz. To the extent inverter 756 supplies electricity to other loads, such as directly to a utility company for the re-sale of electricity thereto, the voltage level and frequency may be adjusted to whatever is suitable for the intended load.

[00173] A more detailed schematic of one embodiment of charge controller 754 is illustrated in FIG. 39. It will be understood by those skilled in the art that the construction and design of charge controller 754 may vary substantially from that shown in FIG. 39. In the embodiment of FIG. 39, charge controller 754 includes an input sensor 776, a digital signal processor (DSP) 778, a memory 780, a plurality of buck converters 782, and an output sensor 784. Input sensor 776 is coupled to hot wire 742a and senses the voltage level and current levels in hot wire 742a. The particular construction of input sensor 776 may take on any suitable form, and may involve an analog-to-digital converter (not shown) that outputs a digital signal to DSP 778 indicating the voltage and current levels of hot wire 742a. After passing through input sensor 776, hot wire 742a is fed into a plurality of parallel arranged buck converters 782 that reduce the DC voltage of hot wire 742a to a more suitable level. The outputs of the buck converters 782 are combined together and fed into output sensor 784, which senses the current and voltage of the combined outputs of the buck converters 782. The sensed current and

voltage levels are fed back to DSP 778. The outputs from the buck converters 782 are then either coupled to battery 758 or to inverter 756, or to both, depending upon the amount of electricity currently being generated by wind turbine 722 and the electrical needs of inverter 756 and battery 758.

[00174] While other designs may be utilized, the buck converter 782 of the embodiment shown in FIG. 39 operate at a 30KHz switching frequency. The switched output is fed into a torroid inductor (not shown) that smoothes the switched DC into a controlled DC output, which is then fed into output sensor 784. The output voltage level of the buck converters 782 are each controlled by pulse width modulated (PWM) signals sent by DSP 778 along PWM lines #1, #2, and #3. By sending the appropriate pulse width along these lines, DSP 778 is able to change the voltage level of hot wire 742a to a suitably regulated voltage level that may be fed into batteries 758 and/or inverter 756.

[00175] DSP 778 may take on any suitable form. In one embodiment, DSP 778 may be a digital signal processor manufactured by Texas Instruments under the part number TMS320F2802. Of course, other types of DSPs may be used. DSP 778 provides monitoring of all currents and voltages, and provides the DC switching control for buck converters 782. DSP 778 also receives inputs from anemometer 750 and motor 744, which include wind speed, wind direction, and the direction wind turbine 722 is currently facing.

[00176] The voltage generated by wind turbine 722 and supplied to hot wire 742a may, in some embodiments, range as high as 350 volts. In other embodiments, higher voltages may be generated and processed by control system 724. DSP 778 uses the sensed voltage and current from input sensor 776 to compute the power and impedance at any given time from wind turbine 722. Using a known, pre-calculated impedance for maximum power, calculated from tested power curves for wind turbine 722, DSP 778 matches the impedance in real time to provide maximum power to the load that is available from turbine 722 at any given time. DSP 778 is thus configured to achieve a maximum power point at any wind speed by matching the source impedance to the load impedance.

[00177] As noted above, hot wire 742a is fed into three parallel buck converters 782. The buck converters may contain a MOSFET, a MOSFET driver, and an inductor. Based on the available power determined from the calculated input impedance along with what is compared to the known available power, DSP 778 will adjust the on and off time of the MOSFETs via the PWM signals sent along PWM lines #1, #2, and #3. By increasing the on time (i.e. the duty cycle of the PWM signals), more power will be delivered to the load. Conversely, by reducing the on time, less power will be delivered to the load. Further, the PWM signals determine the impedance of the control system, and, as a result, the PWM signals can be adjusted such that the turbine impedance matches the control system's impedance for maximum power delivery.

[00178] Different numbers of buck converters may be used other than the three illustrated in FIG. 39, such as, but not limited to, four buck converters 782, five, or other numbers. Further, in some embodiments, more than one buck converter 782 may be on at the same time. For example, if four

buck converters 782 are utilized, they may be used in a 180 degrees phase shifted manner whereby two buck converters 782 are on and the other two buck converters 782 are off. This distributes the heat generated within the buck converters across multiple converters, thereby allowing lower cost buck converters to be used.

[00179] The buck converters 782 may be arranged in parallel and utilized individually at a suitable frequency, such as, but not limited to, 30KHz, wherein their individual usage is synchronized with each other and phase shifted by 120 degrees. This phase shifting allows only one of the buck converters to be on at any one time. This causes the wind turbine to see a switch frequency that is three times the frequency of the individual buck converters 782 (such as 90KHz) when three buck converters 782 are used, and allows the heat generated by each buck converter 782 to be spread out amongst the multiple buck converters, thereby allowing lower cost MOSFETs to be used. The voltage output from the MOSFETs is fed inside the buck converter to an inductor and capacitor (not shown) that smooth out the DC switching ripples. The result is a controlled DC output from the buck converters 782 that has a voltage proportional to the on time of the switching MOSFETs.

[00180] Output sensor 784 senses the voltage and current of the combined outputs of the buck converters 782 and passes this information to DSP 778. DSP 778 uses this information to calculate the output voltage and the current being provided to battery 758 for charging, or being supplied to inverter 756, or both. If battery 758 is in need of charging (as determined by any suitable connections and/or monitoring circuitry between battery 758 and DSP 778), DSP 778 will, in at least one embodiment, use a multistage charging algorithm to charge battery 758 or batteries 758. In a first stage, DSP 778 provides a bulk charge that replaces approximately 70-80% of the batteries' state of charge at a fast rate. This bulk charge stage uses a constant current algorithm that supplies a constant current to the batteries.

[00181] Following the constant current re-charging stage, DSP 778 may implement an absorption stage. The absorption stage replenishes the remaining 20-30% of the charge by bringing the batteries to a full charge at a relatively slow rate. The absorption charge stage supplies a constant voltage algorithm that maintains a constant voltage to the batteries. After the absorption stage, a float stage may be provided by DSP 778. The float stage reduces the voltage and holds it constant in order to prevent damage to the batteries and to keep the batteries at full charge.

[00182] While other types of batteries may be used, battery 758 may be, in one embodiment, a conventional automobile battery. Further, as has been noted, multiple batteries 758 may be ganged together to provide a greater reserve of electrical energy for supply to distribution panel 760 when the wind conditions are not sufficient to allow wind turbine 722 to supply all of distribution panel 760's current electrical needs. Other types of batteries, such as those that supply less instantaneous power but greater long-term power, may also be used. Indeed, in some embodiments, it may be desirable to avoid using automotive batteries because such batteries are designed for short term supply of large

currents where the battery is not deep cycled. For use in electrical generation system 720, or 820 (as discussed more below), it may be beneficial to use batteries that are specifically designed to be deep cycled often, such as, but not limited to, batteries that are capable of being discharged down to at least 80% of their charge time after time. Such batteries typically have solid lead plates, rather than sponge lead plates. Such batteries will allow greater ease in time-shifting the electricity usage of generation system 720 and 820 wherein the time between the generation of the electricity (i.e. when the wind is blowing) and the time when the electricity is used, may be greater. Further, such batteries will allow more power to be supplied to the home or business in the absence of wind. Other advantages of deep cycle batteries may also arise.

[00183] In some embodiments, DSP 778 is programmed to prevent battery 758 from experiencing a deep cycle discharge except when DSP 778 senses an interruption in utility supplied power. This feature is implemented when the particular type of battery being used will have its life shortened by deep cycling. When DSP 778 senses an interrupt in the utility supplied power, which may be accomplished by any suitable connection to distribution panel 760 (not shown), or other known means, DSP 778 is programmed to automatically couple battery 758 to distribution panel 760 and allow battery 758 to discharge for as long as the utility-power remains cut off. This feature allows uninterrupted power to be delivered to the electrical products that receive their electrical power from the particular circuit, or circuits, of distribution panel 760 that are integrated with electrical generation system 720.

[00184] Further, DSP 778 may be programmed to selectively apply the power from battery 758 to particular circuits of distribution panel 760 upon the failure of utility-supplied power. For example, DSP 778 may be programmed to couple battery 758 to those circuits deemed most critical to maintain during a power outage. Such circuits may, for example, include the circuits that supply electricity to the home or business's sump pump, the furnace, or the like. When DSP 778 senses that utility-supplied power has returned, it commences re-charging the one or more batteries 758. In one embodiment, if no wind is available at that particular time, DSP 778 sends out a command to transfer switch 774 (FIG. 38) commanding it to switch in a manner that couples suitable utility-supplied electrical power to battery 758 to recharge it. In another embodiment, if no wind is available at that particular time, DSP 778 waits to recharge the one or more batteries 758 until sufficient wind returns. In either embodiment, if there is insufficient wind currently available and battery 58 is insufficiently charged to adequately supply distribution panel 760, DSP 778 couples the utility-supplied power back to all of the circuits of distribution panel 760 such that power to the electrical products in the home or business is not interrupted. This utility-supplied power will continue to be supplied until sufficient wind power returns to once again switch off the utility-supplied power.

[00185] DSP 778 may receive its power from one or more of batteries 758, or it may receive its power from a utility-supplied source, or it may receive its power from wind turbine 722, or any combination of these three sources. Whatever the source, DSP 778 is configured such that it will still

receive sufficient electrical power to carry out its control operations even during power outages of the utility-supplied electrical power. Indeed, in some embodiments, DSP 778 may be supplied by one or more batteries separate from batteries 758 that exclusively supply power to charge controller 754 and/or the other electrical components housed within enclosure 762.

[00186] In order to prevent damage to wind turbine 722, DSP 778 communicates with motor 744 and sends motor commands based upon the wind speed and direction sensed by anemometer 750. DSP 778 repeatedly determines whether the wind is excessive for wind turbine 722 by comparing the measured wind speed to a threshold stored in memory 780 of controller 754. The threshold is based upon the particular wind turbine 722 that is being used, and may vary between different models of wind turbines 722. The threshold wind speed stored in memory 780 represents a speed above which damage may occur to wind turbine 722. DSP compares the measured wind speed from anemometer 750 to the threshold wind speed and, if the measured wind speed exceeds the threshold speed, DSP 778 sends a command to motor 744 to rotate wind turbine 722 such that it no longer faces directly into the wind. By turning wind turbine 722 out of direct alignment with the wind during high-wind conditions, the likelihood of damage to wind turbine 722 is reduced.

[00187] DSP 778 further rotates wind turbine 722, via motor 744, depending upon the amount by which the currently measured wind speed exceeds the threshold wind speed stored in memory 780. The greater the amount by which the currently measured wind speed exceeds the threshold wind speed, the greater the amount of misalignment of wind turbine 722 with respect to the wind direction DSP 778 commands. That is, the higher the wind speed above the threshold, the higher the rotation of wind turbine 722 out of direct alignment with the wind direction. By rotating wind turbine 722 more and more out of alignment with the wind during ever increasing wind speeds, the wind pressure applied to blades 726 is reduced, and the likelihood for damage to wind turbine 722 is also reduced.

[00188] When DSP 778 senses that the current wind speed has decreased, it sends suitable commands to motor 744 causing wind turbine 722 to rotate back toward the current wind direction. If the current wind speed drops to the threshold wind speed, or below, DSP 778 sends commands to motor 744 to rotate wind turbine 722 such that it is directly aligned with the current wind direction. DSP 778 and motor 744 thus work in cooperation to ensure that the wind turbine 722 is always facing directly into the wind whenever the wind speed is below the threshold wind speed, and is facing out of alignment with the wind by an amount that is related to the amount by which the threshold speed is exceeded.

[00189] Depending upon the voltage in hot wire 742a, processor 778 may couple hot wire 742a directly to inverter 756, rather than to battery 758, when sufficient power is being generated by wind turbine 722 to supply the one or more circuits of distribution panel 760 that are electrically coupled to power generation system 720. Such direct coupling improves the efficiency of system 720.

[00190] Charge controller 754 may be coupled to a display panel 786, which may be a liquid crystal display (LCD), or other type of display panel (FIGS. 38-39). DSP 778 is configured to allow a variety of different types of information to be selectively displayed on display panel 786. One or more buttons 788, or other types of user interface devices, may also be coupled to DSP 778 so as to enable a person to control what information is displayed on display panel 786. DSP 778, in one embodiment, is configured to allow the following information to be displayed on display panel 786: power currently being generated, current wind speed, current wind direction, current open voltage, current load voltage, current battery voltage, cumulative energy generated to date, time, date, year, charging status, and any faults.

[00191] Electrical generation system 720 may be configured to sink any excess electricity it generates into a dummy resistive load (not shown), or it may supply such excess power to a water heater, or it may supply it back to the utility. That is, when all of batteries 758 are fully charged and wind turbine 722 is supplying more electricity than is currently being demanded by the associated loads on distribution panel 760, system 720 may transfer the excess electricity being generated to any of these, or other, destinations. DSP 778 may further be configured to keep track of how often such periods of excessive electricity generation occur, and/or the amount of excessive power that is generated. This information may be displayed on panel 786 and provide an indication to a user of system 720 as to how frequently system 720 is generating more electricity than is being consumed. If this occurs frequently, the user may wish to add further batteries 758 and/or to couple system 720 to a greater number of circuits within panel 760, or to couple system 720 to different circuits within distribution panel 760 that have larger or more frequent loads.

[00192] FIGS. 40-42 illustrate in more detail an embodiment of electrical generation system 820. The embodiment shown in FIGS. 40-42 includes multiple components in common with electrical generation system 720, and those common components bear the same label as they do in system 720 and operate in the same manner as they do in system 720, unless otherwise noted. Such common components therefore do not need to be described in greater detail.

[00193] As shown in FIG. 40, electrical generation system 820 includes wind turbine 722 and a control system 824. Cable 742 connects wind turbine 722 to control system 824. A control cable 796 and a motor rotation cable 798 also pass between wind turbine 722 and control system 824. Cables 796 and 798 may be bundled together with cable 742, or they may be separately bundled. Cables 742, 796, and 798 are of a sufficient length such that control system 824 may be physically positioned remotely from wind turbine 722 at a location that is more convenient for storing control system 824. As but one example, cables 742, 796, and 798 may be sufficiently long to allow control system 824 to be positioned inside of a home, building, garage or other enclosure protected from the elements.

[00194] Electrical generation system 820 further includes one or more batteries 758 for storing unconsumed electricity generated by wind turbine 722. As with system 720, controller 824 of system

820 charges batteries 758 when electricity is currently being generated by turbine 722 that exceeds the electrical demands being placed upon system 820. Similarly, controller 824 of system 820 utilized batteries 758 to meet electrical demands that exceed the contemporaneous electricity generating capability of turbine 722. Controller 824 thus utilizes one or more batteries 758 for storing excess electricity for supply at later times, if needed.

[00195] As is further shown in FIG. 40, electrical generation system 820 includes AC transfer switch 774 that allows the system to be selectively coupled to, and decoupled from, the AC power supplied by an electrical utility. Such coupling is desirable when insufficient wind is currently available for conversion to electricity and the charge level of the batteries 758 is likewise insufficient to meet the current electrical demand. Such decoupling is desirable when the batteries 758 and/or wind turbine 722 are able to provide sufficient electricity to meet the current electrical demands placed upon the system 820.

[00196] As is illustrated in greater detail in FIG. 41, control cable 796 is operatively coupled to a control circuit 800 that may be housed within a turbine interface enclosure 802. Control circuit 800, in turn, receives inputs from both a wind speed sensor, such as an anemometer 750, and a wind direction sensor 804. Control circuit 800 further receives inputs from first and second limit switches 806a and 806b. Limit switches 806a and 806b detect when turbine 722 has rotated to its extreme limits about shaft 730. In one embodiment, turbine 722 may be configured such that it is able to rotate approximately 340 degrees about the vertical axis defined by shaft 730. Other ranges of rotation may also be implemented, including configurations in which turbine 722 is free to rotate a full 360 degrees about shaft 730. When control circuit 800 receives a signal from either of limit switches 806a or 806b, it sends a signal along logic control cable 796 to control system 824. Control system 824 may then terminate power to rotation motor 744 by ceasing to supply an electrical current to motor 744 via motor rotation cable 798. Alternatively, or in addition, control circuit 800 may directly disable any power supplied to rotation motor 744 by cable 798 through appropriate switching. However implemented, limit switches 806 serve to prevent motor 744 from attempting to rotate turbine 722 past its prescribed range of rotational motion. Any such disabling of power to rotation motor 744 is limited to only disabling power that would cause turbine 722 to move further in the direction that caused the limit switch to be activated. That is, rotation motor 744 is prevented from moving past the outer boundaries of its limited range of motion, but is still free to rotate within those boundaries.

[00197] Turbine interface enclosure 802 may further include a diversion load control 808, which acts to sink excessive current generated by wind turbine 722 when the wind speed is high enough to generate more electricity than can be safely processed by control system 824. In at least one embodiment, control system 824 may be configured to be able to process 170 volts DC from wind turbine 722. Other embodiments may vary this number, either higher or lower. In at least one embodiment, diversion load control 808 will engage a diversion load if the turbine is currently

generating 170 volts or more. Such engagement may happen without any input or signals from control system 824. In other words, diversion load control 808 may act autonomously to engage the diversion load.

[00198] Diversion load control 808 may also include a maximum overvoltage protection circuit 810 that prevents a maximum output voltage from being exceeded by wind turbine 722. As one example, such maximum overvoltage might be set at 250 volts. Other values can, of course, be used. If the diversion load of diversion load control 808 fails to limit the voltage, and the voltage output from turbine 722 tries to increase above 250 volts (where 250 volts is the illustrative maximum), circuit 810 will clamp the voltage and blow a fuse 812. This will prevent an overvoltage condition that could create a fire risk to components that have rated maximums of 250V downstream of the turbine interface enclosure 802. In such a situation, the turbine will let loose and will spin at an uncontrolled speed.

[00199] Turbine interface enclosure 802 is connected to control system 824 via cables 742, 796, and 798, as was noted previously. Cable 742 supplies the DC voltage generated by turbine 722 to control system 824. Control cable 796 supplies signals to controls system 824 indicating the direction of the wind, the speed of the wind, and, in at least some embodiments, the current position of the rotation motor 744. Cable 798 supplies power to rotation motor 744, causing it to turn in a manner controlled by control system 824, and as has been described previously. That is to say that control system 824 controls rotation motor 744 such that, in excessive wind conditions, turbine 722 is turned out of the wind a sufficient amount to prevent more than the rated amount voltage from being generated, and in less-than excessive wind conditions, turbine 722 is turned into the wind.

[00200] FIG. 42 illustrates an embodiment of control system 824 in greater detail. The components of control system 824 that are common to control system 724 are labeled with the same number and operate in the same manner as previously described, unless indicated to the contrary. Control system 824 includes an I/O board 814 which includes various electrical components for interfacing with turbine interface enclosure 802, as well as charge controller 754 and inverter 756. Cables 742, 796, and 798 feed into I/O board 814. More specifically, cable 742 feeds into a DC ground fault interrupter 816, before passing onto a current/voltage sensor 776. A suitable fuse may be positioned between cable 742 and GFI 816. Current/voltage sensor 776 operates in the same manner as previously described and senses the current and voltage currently being generated by wind turbine 722. This information is passed onto charge controller 754, including its digital signal processor 778, which uses the information to process the voltage generated by turbine 722 in the manner previously described.

[00201] Control system 824 further includes a rotation motor control circuit 815 that outputs control signals causing rotation motor 744 to rotate in the desired manner. Rotation motor control circuit 815 receives control inputs from isolated logic control 817. Isolated logic control 817, in turn, receives signals from logic control cable 796. These signals, as noted previously, indicate the current wind

speed and direction, as well as which limit switch 806, if any, has been activated. Logic control cable 796 may further transmit information indicating the current rotational orientation of motor 744 to isolated logic control circuit 817. Isolated logic control circuit 817 uses the information it receives from control cable 796 to determine what changes, if any, should be made to the orientation of wind turbine 722. Such changes, if any, are communicated to rotation motor control 815, which then sends appropriate signals on cable 798 to rotation motor 744 that cause rotation motor 744 to turn in the desired manner.

[00202] Control system 824 further includes output sensor 784, which measures the voltage and current being output by charge controller 754. Control system 824 also includes a pair of additional current/voltage sensors 818a and 818b that measure the current and voltage passing through two other locations of control system 824. Sensor 818a measures the voltage and current being output by control system 824. That is, sensor 818a measure how much current and voltage is being supplied by electrical generation system 820 for usage within a house, building, or other facility. Sensor 818b measures the voltage and current being supplied to inverter 756. DSP processor 778 uses the information from sensors 818a and 818b in controlling the charging/discharging of the bank of batteries 758, as well as in controlling A/C transfer switch 774. As was noted, A/C transfer switch 774 switches between having turbine 722 provide power and the electrical utility (AC grid) provide power to the house, building, facility, or particular circuit(s) within one of these units.

[00203] System 824 monitors the output of sensor 818a to determine whether to switch to the AC grid or not. In at least one embodiment, system 824 is configured to switch to the AC grid whenever the total load being placed upon the electrical generation system 820 exceeds system 820's current electrical production capabilities, taking into account both the electrical production from turbine 722 as well as the electrical production from batteries 758. Thus, for example, suppose that a 1000 watt load is being applied to system 820. Suppose further that system 820 was configured such that it supplied 24 volts to inverter 756, whether from batteries 758 or charge controller 754. Still further, suppose that the wind was currently blowing at a speed that enables 15 amperes of current to be generated from wind turbine 722. Another 26.6 amperes of current would then have to be drawn from the battery to meet the 1000 watt demand. Batteries 758 would then slowly discharge as they continued to supply these 26.6 amperes. Once the batteries were discharged, system 824 would switch back to the AC grid, via switch 774, and turn inverter 756 off. Further, system 824 would start charging the batteries using the fifteen amperes of current available from wind turbine 722. While the batteries were recharging, the AC grid would supply all of the 1000 watts to the load. Only after the batteries 758 were fully recharged, or charged to within a threshold of their full charge—which could be a variable threshold and which could be programmable—would system 824 switch off of the AC grid and back to receiving power from wind turbine 722 and the batteries. In this manner, system 824 either uses or stores the wind energy whenever it is available, unless the batteries are all charged and no electrical demands are present.

[00204] FIG. 43 shows a chart of the various states that may be assumed by either of electrical generation systems 720 or 820. Such states are, of course, only one possible configuration that may be applied to systems 720 and 820, and it will be understood that either or both of system 720 and 820 can be configured in manner different from that shown in FIG. 43. The current state of system 720 or 820, as shown in FIG. 43, may be viewable on an LCD screen of display pad 786. The left-most column in FIG. 43 indicates the state of system720 or 820. The next column provides a description. The "charger" column indicates whether the charge controller 754 is on, waiting, or in some other condition. The "inverter" column indicates the state of the inverter 756. The "TS" column indicates the state of the transfer switch 774. The "dump" column indicates whether electricity is being routed to the diversion load by diversion load control 808 or not. FIG. 43 thus provides one example of the manner in which system 720 or 820 may be controlled via control system 724 or 824. Other manners may also, of course, be used.

[00205] As has been described above, DSP 778 of electrical generation systems 720 and 820 may be programmed such that the PWM signals sent to the buck converters 782 are adjusted so that the source impedance (turbine 722) matches the load (control system 724) impedance. Such embodiments tend to produce power that follows the wind speed. An example of this is seen in FIGS. 44A and 44B. FIG. 44A illustrates an arbitrary wind speed with respect to time wherein the wind speed is represented by the curve 792. When DSP 778 is programmed to continually adjust its load impedance so that it matches the turbine impedance, the power output will generally follow the wind speed, as illustrated in FIG. 44B by the power curve 794, where the shape of the power curve generally matches the shape of the wind speed curve 792 of FIG. 44A. Such continuous impedance matching, however, can be modified in some embodiments of electrical generation system 720 and 820.

[00206] For example, either of electrical generation systems 720 and 820 may be modified to create power pulses generally like the pulses 795 illustrated in FIG. 44C (when subjected to wind speeds like that shown in FIG. 44A). In the embodiment represented by FIG. 44C, DSP 778 controls buck converters 782 to generate input impedances that alternate between being higher and lower than the impedance of turbine 722. This creates the power peaks shown in FIG. 44C. Such power peaks will transiently exceed the power generated by the system shown in FIG. 44B. In other words, for example, the power represented by reference letter B in FIG. 44B is lower than the peak power represented by the reference letter C in FIG. 44C, despite the fact that both powers are generated at the same moment in time (identified by the reference letter "A") under the same wind conditions. Because of the higher peaks of the system of FIG. 44C relative to the system of FIG. 44B, the system of FIG. 44C may be more effective at charging the batteries 758 than the system of FIG. 44B, particularly at low wind speeds. What qualifies as a low wind speed will naturally vary from turbine to turbine, but in at least one embodiment, such low wind speeds may refer to any wind speeds below

seven miles per hour. In other embodiments, a lower or a higher speed might be considered "low speed," depending, as noted, upon the wind speeds for which the wind turbine is designed.

[00207] DSP 778 may alter the input impedance of the control system to create the pulses of FIG. 44C by appropriately changing the pulse-width modulation (PWM) signals sent to buck converters 782. Such alteration may involve changing the duty cycle of the PWM signals during the pulses and in the interim time periods between the pulses. It will be understood by those skilled in the art that the shape of the power pulses illustrated in FIG. 44C is merely for purposes of illustration, and that the actual shape will typically not be precisely rectangular shapes, but will be shaped to have ramp up and ramp down slopes that vary depending upon the overall construction of the systems, as well as the pulsing.

[00208] One of the results of the pulsed power extraction technique illustrated in FIG. 44C is to extract a certain amount of the kinetic energy of the rotating blades of the turbine out of the turbine in pulses and to convert it to pulsed electrical energy. This pulsed extraction of the kinetic energy from the rotating blades causes the blades to slow down during the energy extraction periods and, assuming the wind continues to blow, to speed back up during the interim periods between pulses.

[00209] As was noted above, DSP 778 may be programmed to utilize the pulsed power extraction technique illustrated in FIG. 44C during low wind speed conditions. In such embodiments, DSP 778 may be programmed to check the wind speed detected by anemometer 750, compare it to a threshold value that defines a low-wind speed condition, and if the current wind speed exceeds the threshold, use the continuous power extraction technique illustrated in FIG. 44B. On the other hand, if the current wind speed is at or beneath the threshold, DSP will switch to a pulsed power extraction technique, such as that shown in FIG. 44C. Various forms of hysteresis may be used to help avoid excessive switching in variable speed winds at or near the threshold. Still further, in any of the embodiments, DSP 778 may be programmed to check to see if the wind speed exceeds a maximum wind speed threshold that is set higher than the low-wind speed threshold. Wind speeds above the maximum wind speed threshold may cause DSP 778 to rotate wind turbine 722 out of direct alignment with the wind, or to stop power generation completely.

[00210] In some embodiments, DSP 778 may switch between the continuous power extraction and pulsed power extraction techniques of FIGS. 44B and 44C based upon the voltage being generated by turbine 722, rather than a direct measurement of the wind speed. Other quantities besides voltage and wind speed may be utilized for switching between these power extraction techniques. Further, DSP 778's decision to switch between the pulsed and continuous power extraction techniques may alternatively be based, at least partially, upon the charge level status of the one or more connected batteries 758. For example, if a low wind speed is present and the batteries are fully charged,

[00211] In some embodiments, it may be desirable to not harvest any electricity from turbine 722 when the voltage generated by turbine 722 is below a threshold. As but one example, it may be

desirable to not harvest any electricity when the wind speeds are such that turbine 722 can only generate less than fifty volts. Whatever the precise threshold, control system 724 may be programmed to allow turbine 722 to free spin when the wind speeds are such that the voltage is less than the threshold. Such a threshold will therefore be referred to herein as the free spin threshold. Still further, if the wind speeds increase such that more than fifty volts are able to be generated by wind turbine 722, but the wind speeds still qualify as low speeds (as discussed above with respect to FIG. 44C), then DSP 778 may be programmed to utilize the pulsed power extraction technique of FIG. 44C. In such a case, the length of each pulse may last until the voltage extracted decreases down to the free spin threshold. Once the free spin threshold is reached, the pulse of the power extraction will be discontinued until wind turbine has a chance to regain a sufficient speed for another pulse of power extraction.

[00212] One illustrative example of the pulsed power extraction technique described in the immediately preceding paragraph will be provided herein for purposes of better understanding the concepts. It will, of course, be understood by those skilled in the art that this description is merely exemplary, and that the precise values described can be changed. Suppose, for example, that it is desirable to have wind turbine 722 free spin at voltages of less than fifty volts. In those cases where the wind increases slightly above this free spin threshold, DSP 778 may be programmed to extract power from wind turbine 722 in a pulsed manner whereby each pulse lasts for the time it takes to bring the voltage back down to near or at the free spin threshold. For instance, DSP 778 may allow turbine to free spin up to 60 volts; then extract power in a pulse that lasts until the voltage drops to 50 volts; then allow turbine 722 to free spin again until 60 volts are reached again; then extract power again in another pulse until the voltage drops to 50 volts, and so on. The upper limit (in this case 60 volts) can vary, but may correspond to the threshold voltage that defines a low speed wind condition, as discussed above with respect to FIG. 44C. The duration or period of the pulse may vary with changes in the wind speed, or other factors that affect the length of time it takes for the voltage to drop to the free spin threshold.

[00213] In an alternative embodiment, the pulse period may be fixed, or it may vary based on other factors, such as wind speed, battery charge level, the electrical load, or other still other factors. With a fixed pulse period, DSP 778 may alter the PWM signals, thereby altering the input impedance, for a fixed amount of time, regardless of the drop in voltage caused thereby.

[00214] In still other embodiments, DSP 778 may extract power in a pulsed manner without allowing the wind turbine to free spin. In such cases, DSP 778 may vary the input impedance of control system 724 between levels that are alternatingly above and below the impedance of wind turbine 722. The lower impedance may not drop all the way to zero, or otherwise cause wind turbine 722 to free spin. Instead, the impedance may drop to a level that, while mismatched below the impedance of wind turbine 722, still causes electricity to be generated. Such an embodiment will alter the graph of FIG.

44C from a series of pulses spaced by intervening periods of zero power, to a series of pulses spaced by intervening periods of non-zero, but reduced (relative to the peaks), power.

[00215] It will be understood by those skilled in the art that the specific electronic and electrical components described in the aforementioned embodiments may be changed to other electrical components and electronics that perform similar functions. For example, the buck converters described herein may be replaced with other switching converters, or other converters that operate in a non-switched manner. Similarly, the control of the buck converters, or other types of converters, may be changed from that utilizing pulse width modulated signals to other types of control signals. Other modifications are also possible.

[00216] It should be understood that the embodiments shown in the drawings and described above are merely for illustrative purposes, and are not intended to limit the scope of the invention which is defined by the claims which follow as interpreted under the principles of patent law including the doctrine of equivalents.

What is claimed is:

1. A wind turbine comprising:

a plurality of wind turbine blades mounted to a rotating member for rotation about an axis of rotation, each of said blades and said rotating member having an angular velocity;

a plurality of magnets supported and spaced outwardly from said axis of rotation and having an angular velocity of at least the angular velocity of said blades and greater than the angular velocity of said rotating member, said magnets each having two opposed major surfaces, said major surfaces extending in a direction generally parallel to axis of rotation; and

a conductive coil, said coil being sufficiently close to at least one of said major surfaces of at least one magnet of said magnets such that rotary movement of said at least one magnet induces current flow in said coil.

2. The wind turbine according to claim 1, wherein said coil straddles said magnet wherein said coil is sufficiently close to each of said major surfaces of said at least one magnet, and said coil being configured so that current flow induced by both said major surfaces of said magnet in said coil is additive.

3. The wind turbine according to claim 1, further comprising a wheel with a plurality of spokes and an annular rim supported by said spokes, said magnets being mounted at said rim.

4. The wind turbine according to claim 3, wherein said turbine blades are mounted to said spokes.

5. A wind turbine comprising:

a plurality of wind turbine blades mounted to a rotating member for rotation about an axis of rotation, each of said blades having a proximal end adjacent said rotating member and a distal end;

an annular rim extending around said distal ends of said turbine blades, each of said distal ends of said blades being decoupled from said rim;

a plurality of magnets supported by said rim wherein said magnets have an angular velocity of at least the maximum angular velocity of said blades; and

a conductive coil, said coil being sufficiently close to said at least one magnet of said magnets such that rotary movement of said at least one magnet induces current flow in said coil.

6. The wind turbine according to claim 5, further comprising a wheel with a plurality of spokes, said wheel including said rim, and said rim being supported by said spokes.

7. The wind turbine according to claim 6, wherein said turbine blades are mounted to said spokes.

8. The wind turbine according to claim 5, wherein said coil straddles two opposed sides of said at least one magnet and being configured so that current flow induced by both sides of said magnet in said coil is additive.

9. A wind turbine comprising:

a wheel including a hub for mounting said wheel about an axis of rotation, a rim, and a plurality of spokes supporting said rim at said hub, a first group of said spokes extending from a first set of spaced connections at said hub to a second set of spaced connections arranged along annular path on said rim, and a second group of spokes extending from a third set of spaced connections at said hub to a fourth set of spaced connections along said annular path on said rim, said first set of spaced connections being spaced along said axis of rotation from said third set of spaced connections wherein said first group of spokes is offset from said second group of spokes at said hub; and

a plurality of wind turbine blades mounted to said spokes.

10. The wind turbine according to claim 9, wherein said wheel supports a plurality of magnets for inducing current flow in a stator assembly.

11. The wind turbine according to claim 10, wherein said rim supports said magnets.

12. The wind turbine according to claim 9, wherein each of said turbine blades comprises a flexible membrane.

13. The turbine according to claim 12, wherein each of said turbine blades includes a frame, said flexible membranes mounted to said frames.

14. The turbine according to claim 13, wherein said flexible membrane comprise a fabric sheet or a polymer sheet.

15. The turbine according to claim 12, wherein at least one of said turbine blades is configured to adjust its solidity.

16. A wind turbine comprising:

a rotary member mounted for rotational motion about an axis of rotation;

a plurality of wind turbine blades supported by said rotary member, each of said blades have a blade root and a blade tip and a maximum angular velocity at said blade tip, said blade roots located adjacent said rotary member, and each of said blades having a varying attack angle, said attack angle decreasing from said blade root to said blade tip;

a plurality of magnets supported by and spaced outwardly from said rotary member and located such that said magnets have an angular velocity of at least the maximum angular velocity of the blades; and

a conductive coil, and said coil being sufficiently close to at least one of said magnets such that rotary movement of said magnets induces current flow in said coil.

17. The turbine according to claim 16, wherein each of said blades has an asymmetrical cross-section.

18. The turbine according to claim 16, further comprising a base, said rotary member mounted for rotational movement about said base about another axis of rotation.

19. A wind turbine comprising:

a rotary member having an axis of rotation;

a plurality of wind turbine blades supported for rotary motion by said member about said axis of rotation, each of said blades having a wind facing surface formed from a sheet of polymer or a sheet of fabric;

a plurality of magnets supported by and spaced outwardly from said rotary member and said axis of rotation; and

a conductive coil, and said coil being sufficiently close to at least one of said magnets such that rotary movement of said magnets induces current flow in said coil.

20. The wind turbine according to claim 19, further comprising a wheel with a plurality of spokes and an annular rim supported by said spokes, said turbine blades are mounted to said spokes.

21. The wind turbine according to claim 20, wherein said magnets being mounted at said rim.

22. A wind turbine comprising:

a rotary member having an axis of rotation, said rotary member having a plurality of radially extending arms; and

a plurality of wind turbine blades supported by said arms, each of said blades being supported by said arms by a flexible coupler wherein said blades move in a direction generally parallel to said axis of rotation in response to wind having a wind speed that exceeds a selected maximum wind speed.

23. The wind turbine according to claim 22, further comprising a plurality of magnets supported by and spaced outwardly from axis of rotation such that said magnets have an angular velocity of at least the angular velocity of the blades.

24. The wind turbine according to claim 23, further comprising a conductive coil, said coil located at said tips or outwardly from said tips of said blades, said coil being sufficiently close to at least one of said magnets such that rotary movement of said magnet induces current flow in said coil.

25. A wind turbine comprising:

a plurality of wind turbine blades mounted for rotational motion about an axis of rotation, said blades having an outer periphery;

a base, said turbine blades mounted for rotation movement about another axis of rotation relative to said base; and

said wind turbine being adapted to harness and direct wind from beyond the outer periphery of said turbine blades into said turbine blades.

26. The wind turbine according to claim 25, further comprising:

an air collector extending around said blade tips, said collector having a conical surface extending from radially outward from said blade tips in the windward direction to direct air into said turbine blades.

27. The wind turbine according to claim 26, said conical surface extends at outward angle of about 60 degrees relative to said axis of rotation.

28. The wind turbine according to claim 26, said collector further including extended portions extending outwardly from said conical surface and in the leeward direction, said extended portions forming apexes with said conical surface.

29. A wind turbine blade comprising:

a frame; and

a web extending between said frame, said web formed from a flexible membrane.

30. The wind turbine blade according to Claim 29, wherein said web is adapted to decrease the solidity of the blade in response to a pre-selected wind speed.

31. The wind turbine blade according to Claim 30, wherein said web comprises a first web extending between a portion of said frame and a second web extending between another portion of said frame, said first web being substantially contiguous with said second web to form therewith a substantially continuous wind facing surface of said blade, said second web formed from a flexible membrane and being mounted to said frame in a manner to allow said second web to form an opening between said first web and said second web.

32. A system for generating electricity from wind comprising:

a wind turbine having a plurality of blades adapted to rotate about an axis and to thereby generate an output voltage, said wind turbine having an electrical impedance; and

a control subsystem for said wind turbine, said control subsystem having a variable impedance controlled by a controller, wherein said controller is adapted to extract power from said wind turbine in a pulsed manner by changing said variable impedance of said control subsystem between levels that are below and above said electrical impedance of said wind turbine.

33. The system of claim 32 wherein said controller is further adapted to match said impedance of said control subsystem to said electrical impedance of said wind turbine such that power is extracted in a non-pulsed manner while a wind speed is less than a threshold wind speed.

34. The system of claim 32 wherein said controller stores an upper threshold voltage and a lower threshold voltage, and wherein said controller changes said variable impedance of said control subsystem based upon said output voltage of said wind turbine reaching said upper threshold and lower threshold voltages, said lower threshold voltage corresponding to a wind speed below which said wind turbine is designed to free spin.

35. The system of claim 32 further including:

a first sensor for determining wind direction;

a second sensor for determining wind speed;

a motor adapted to change an orientation of said axis; and

wherein said controller is in communication with said first and second sensors and said controller is adapted to activate said motor such that said axis aligns with the wind direction when the wind speed is less than a set wind speed, and said controller is further adapted to activate said motor

such that said axis is misaligned with the wind direction when the wind speed is greater than said set wind speed.

36. The system of claim 32 further including:

a voltage sensor for measuring said voltage output;

a buck converter in electrical communication with said wind turbine voltage output, said buck converter adapted to reduce a voltage level of said wind turbine voltage output;

an inverter adapted to convert direct current into alternating current;

a transfer switch adapted to selectively couple an output from said inverter or a utility-supplied source of electrical energy to a distribution panel;

a battery; and

wherein said controller is adapted to monitor a charge level of said battery and to switch said transfer switch to couple the utility-supplied source of electrical energy to said distribution panel when said charge level of said battery falls below a charge threshold and said output voltage falls below a voltage threshold.

37. A system for generating electricity from wind comprising:

a wind turbine having a plurality of blades adapted to rotate about an axis and to thereby generate an output voltage; and

a control subsystem for said wind turbine, said control subsystem adapted to extract electrical power from said wind turbine in a substantially continuous manner when a wind speed is less than a wind speed threshold, and said control subsystem adapted to extract electrical power from said wind turbine in a pulsed manner when the wind speed is greater than said wind speed threshold.

38. The system of claim 37 wherein said control subsystem includes a controller adapted to extract electrical power from said wind turbine in a pulsed manner by varying input impedances into said control subsystem in a pulsed manner.

39. The system of claim 38 wherein said controller varies input impedances into said control subsystem by varying a duty cycle of a pulse width modulated control signal that controls at least one buck converter.

40. The system of claim 38 wherein said controller is adapted to extract electrical power from said wind turbine in said substantially continuous manner by matching said input impedance into said control subsystem to an impedance of said wind turbine.

41. The system of claim 38 wherein said controller stores an upper threshold voltage and a lower threshold voltage, and wherein said controller changes said input impedance of said control subsystem based upon said output voltage of said wind turbine reaching said upper threshold and lower threshold voltages, said lower threshold voltage corresponding to a wind speed below which said wind turbine is designed to free spin.

42. A control system for a wind turbine having a plurality of blades adapted to rotate about an axis,

said system comprising:

a first sensor for determining wind direction;

a second sensor for determining wind speed;

a motor adapted to change an orientation of said axis; and

a controller in communication with said first and second sensors, said controller adapted to activate said motor such that said axis aligns with the wind direction when the wind speed is less than a threshold, and said controller further adapted to activate said motor such that said axis is misaligned with the wind direction when the wind speed is greater than said threshold.

43. The system of claim 42 wherein said controller is further adapted to activate said motor such that an amount of misalignment of the axis and the wind direction increases with increases in wind speed above said threshold.

44. The system of claim 42 wherein said control system is electrically coupled to a distribution panel adapted to supply electrical power to at least one circuit in a home or building.