(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 January 2015 (29.01.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/013149 A2

(51) International Patent Classification:
*F03D 7/02* (2006.01) *H02K 47/00* (2006.01)
*F03D 9/00* (2006.01) *H02K 7/02* (2006.01)

(21) International Application Number: PCT/US2014/047339

(22) International Filing Date: 21 July 2014 (21.07.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/856,760 21 July 2013 (21.07.2013) US
14/335,890 19 July 2014 (19.07.2014) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17**:
— *of inventorship (Rule 4.17(iv))*

**Published**:
— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

WO 2015/013149 A2

**(54) Title**: SOLAR POWERED WIND TURBINE APPARATUS FOR REDUCING OR ELIMINATING WIND CUT-IN SPEED

**(57) Abstract**: A method and an apparatus are provided for initiating rotation of blades of a wind turbine when wind speed is less than a cut-in speed. A solar powered wind turbine apparatus includes a solar dome with photovoltaic cells, operably connected to a rotor assembly, and an electric motor. The photovoltaic cells convert solar energy from incident sunlight into electrical energy. The electric motor electrically connected to the photovoltaic cells rotates the blades of the rotor assembly using the electrical energy from the photovoltaic cells. The electric motor powered by the photovoltaic cells initiates the rotation of the blades of the rotor assembly when wind speed is less than the cut-in speed, and therefore reduces or eliminates the cut-in speed required to rotate the blades. The blades of the rotor assembly thereafter continue to rotate in response to a force of wind on the blades and/or the powered electric motor.

# SOLAR POWERED WIND TURBINE APPARATUS FOR REDUCING OR ELIMINATING WIND CUT-IN SPEED

## CROSS REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims priority to and the benefit of provisional patent application number 61/856,760 titled "Solar Powered Wind Turbine Apparatus With Reduced Cut-in Speed", filed in the United States Patent and Trademark Office on 21 July 2013, and non-provisional patent application number 14/335,890 titled "Solar Powered Wind Turbine Apparatus For Reducing Or Eliminating Wind Cut-in Speed", filed in the United States Patent and Trademark Office on 19 July 2014. The specifications of the above referenced patent applications are incorporated herein by reference in their entirety.

## BACKGROUND

**[0002]** Conventional wind turbines harness the energy of wind and convert the energy to a form of mechanical energy. The mechanical energy may further be converted to electrical energy based on the application in which the wind turbine is used. Nearly all conventional wind turbines require a minimum wind speed to rotate their blades. This wind speed is called a cut-in speed. As is known, power output of a wind turbine is directly proportional to a cube of the wind speed. Therefore, for example, about 10% increase in the wind speed results in about 33% increase of power output. Sometimes, the wind does not attain the cut-in speed, resulting in non-rotation of the blades of the wind turbine and therefore non-generation of electric power. However, when the wind attains or exceeds the cut-in speed, the wind turbine rotates at a speed proportional to the wind speed. This dependency on attainment of the cut-in speed by the wind speed reduces the power that is generated by the wind turbine resulting in low electric power production. There is a need for an alternate power source that provides power to initiate rotation of the blades of the wind turbine when the wind is less than the cut-in speed, thereby reducing or eliminating the cut-in speed required to rotate the blades of the wind turbine.

**[0003]** Hence, there is a long felt but unresolved need for a method and an apparatus that provides power to rotate the blades of a wind turbine when the wind speed is less than the cut-in speed, thereby reducing or eliminating a cut-in speed required to rotate the blades of the wind turbine.

SUMMARY OF THE INVENTION

**[0004]** This summary is provided to introduce a selection of concepts in a simplified form that are further disclosed in the detailed description of the invention. This summary is not intended to identify key or essential inventive concepts of the claimed subject matter, nor is it intended for determining the scope of the claimed subject matter.

**[0005]** The method and the solar powered wind turbine apparatus disclosed herein address the above mentioned need for providing power to rotate blades of a wind turbine when the speed of wind is less than a cut-in speed, thereby reducing or eliminating the cut-in speed required to rotate the blades of the wind turbine. The solar powered wind turbine apparatus disclosed herein is configured as a solar powered horizontal axis wind turbine apparatus or a solar powered vertical axis wind turbine apparatus. The solar powered wind turbine apparatus disclosed herein comprises a solar dome with photovoltaic cells, a rotor assembly with blades, and an electric motor. The solar dome is an encasing that houses and supports an interconnected assembly of photovoltaic cells on a surface of the solar dome. The solar dome is operably connected to the rotor assembly. The solar dome is configured to house the photovoltaic cells to enable the photovoltaic cells to receive solar energy from multiple sunlight directions. The solar dome is positioned on multiple, movable and configurable locations on the solar powered wind turbine apparatus. The solar dome protrudes outwardly and is configured to be rotatable to face the sunlight.

**[0006]** The photovoltaic cells housed in the solar dome are exposed to sunlight and convert solar energy from sunlight incident on the photovoltaic cells into electrical energy. The electric motor of the solar powered wind turbine apparatus is electrically connected to the photovoltaic cells housed in the solar dome. The photovoltaic cells transfer the electrical energy generated from the incident sunlight to the electric motor. The electric motor rotates the rotor assembly with the blades using the electrical energy transferred by the photovoltaic cells. The electric motor powered by the photovoltaic cells on the solar dome initiates the rotation of the blades of the rotor assembly when the speed of wind is less than the cut-in speed, and therefore reduces or eliminates the cut-in speed required to rotate the blades of the rotor assembly. Once the blades are set in rotational movement, the blades of the rotor assembly will continue to rotate in proportion to the wind speed and/or the electrical energy produced by the photovoltaic cells. The rotation of the solar dome cools the photovoltaic cells housed in the solar dome with more airflow and decreases the temperature increase of the photovoltaic cells, thereby increasing the efficiency of the photovoltaic cells for producing electrical energy.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** The foregoing summary, as well as the following detailed description of the invention, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, exemplary constructions of the invention are shown in the drawings. However, the invention is not limited to the specific methods and structures disclosed herein. The description of a method step or a structure referenced by a numeral in a drawing carries over to the description of that method step or structure shown by that same numeral in any subsequent drawing herein.

**[0008]** FIG. **1** illustrates a method for initiating rotation of blades of a wind turbine when the speed of wind is less than a cut-in speed, thereby reducing or eliminating the cut-in speed requirement of the wind turbine.

**[0009]** FIG. **2A** exemplarily illustrates a partial side elevation view of a solar powered horizontal axis wind turbine apparatus for reducing or eliminating wind cut-in speed.

**[0010]** FIG. **2B** exemplarily illustrates a partial sectional view of the solar powered horizontal axis wind turbine apparatus, showing an electric motor and a frame.

**[0011]** FIG. **3A** exemplarily illustrates a front elevation view of a solar powered vertical axis wind turbine apparatus for reducing or eliminating wind cut-in speed.

**[0012]** FIG. **3B** exemplarily illustrates a partial cut-away front sectional view of an embodiment of the solar powered vertical axis wind turbine apparatus, showing an electric motor.

**[0013]** FIG. **4** exemplarily illustrates a graphical representation of power output of the solar powered wind turbine apparatus powered by wind energy and solar energy.

DETAILED DESCRIPTION OF THE INVENTION

**[0014]** FIG. **1** illustrates a method for initiating rotation of blades **204** of a wind turbine **200** or **300** exemplarily illustrated in FIGS. **2A-2B** and FIGS. **3A-3B**, when the speed of wind is less than a cut-in speed, thereby reducing or eliminating the cut-in speed requirement of the wind turbine **200** or **300**. As used herein, the term "cut-in speed" refers to a minimum speed of wind at which the blades **204** of a wind turbine **200** or **300** start rotating in response to power from the wind or an alternative source. By way of example, consider a wind turbine **200** or **300** that has a cut-in speed of 5 miles per hour. When the speed of the wind traversing the wind turbine **200** or **300** is, for example, from 0 miles per hour to any speed less than 5 miles per hour, the blades **204** of the wind turbine **200** or **300** will not rotate. When the wind speed traversing the wind turbine **200** or **300** reaches 5 miles per hour, the blades **204** of the wind turbine **200** or **300** will start rotating. In this example, the method disclosed herein reduces the cut-in speed to less than 5 miles per hour. In the method disclosed herein, a solar powered wind turbine apparatus **200** or **300** comprising a solar dome **203**, a rotor assembly **202** or **301** with multiple blades **204**, and an electric motor **215** or **306** as exemplarily illustrated in FIGS. **2A-2B** and FIGS. **3A-3B**, is provided **101**.

**[0015]** The solar powered wind turbine apparatus is configured, for example, as a solar powered horizontal axis wind turbine apparatus **200** as exemplarily illustrated and disclosed in the detailed description of FIGS. **2A**-**2B**, or as a solar powered vertical axis wind turbine apparatus **300** as exemplarily illustrated and disclosed in the detailed description of FIGS. **3A**-**3B**. The solar dome **203** is an encasing that houses and supports a packaged interconnected assembly of photovoltaic cells **206** on the surface of the solar dome **203** as exemplarily illustrated in FIG. **2A** and FIG. **3A**. The solar dome **203** enables the photovoltaic cells **206** to receive **102** the solar energy from multiple sunlight directions. The solar dome **203** is operably connected to the rotor assembly **202** or **301** as exemplarily illustrated in FIGS. **2A**-**2B** and FIGS. **3A**-**3B**. For example, the solar dome **203** is rigidly attached to the rotor assembly **202** or **301**. In an embodiment, the solar dome **203** is rotatable about a horizontal axis X-X **207** as exemplarily illustrated in FIGS. **2A**-**2B**, or about a vertical axis Y-Y **302** as exemplarily illustrated in FIGS. **3A**-**3B**, to enable the photovoltaic cells **206** to receive the solar energy from multiple directions of incident sunlight.

**[0016]** The photovoltaic cells **206** housed in the solar dome **203** are exposed to the sunlight and convert **103** the solar energy received from incident sunlight on the photovoltaic cells **206** into electrical energy by a photovoltaic effect. The photovoltaic cells **206** are made out of a semiconductor material. When a photon is absorbed by the photovoltaic cell **206**, electrons from the atoms of the semiconductor material are dislodged from their positions. These electrons travel toward a front surface of the photovoltaic cell **206** and flow on the front surface of the photovoltaic cell **206**. This flow of electrons generates electrical energy which is transferred to the electric motor **215** or **306**.

**[0017]** The electric motor **215** or **306** of the solar powered wind turbine apparatus **200** or **300** is electrically connected to the photovoltaic cells **206** housed in the solar dome **203**. The photovoltaic cells **206** transfer **104** the electrical energy generated from the incident sunlight to the electric motor **215** or **306**. The electric motor **215** or **306** rotates the rotor assembly **202** or **301** with the rigidly attached solar dome **203**, and therefore rotates **105** the blades **204** housed in the rotor assembly **202** or **301**, using the electrical energy transferred by the photovoltaic cells **206**, thereby reducing or eliminating the cut-in speed required for the rotation of the blades **204**. When the solar powered horizontal axis wind turbine apparatus **200** or the solar powered vertical axis wind turbine apparatus **300** at rest are acted upon by wind, the blades **204** of the rotor assembly **202** or **301** have a tendency to initially rotate in a clockwise direction or a counterclockwise direction, according to the direction of wind. Despite the initial clockwise or counterclockwise rotation of the blades **204** of the rotor assembly **202** or **301** according to the direction of wind, the electric motor **215** or **306** redirects the rotation of the blades **204** in the desired direction, for example, a clockwise direction or a counterclockwise direction. Once the blades **204** are rotated, inertia maintains the blades **204** of the rotor assembly **202** or **301** in rotational motion as a body in motion tends to stay in motion.

**[0018]** The electric motor **215** or **306** powered by the photovoltaic cells **206** on the solar dome **203** provides the initial power to initiate the rotation of the blades **204** of the rotor assembly **202** or **301** when the speed of wind is less than the cut-in speed, thereby reducing or eliminating the cut-in speed required to rotate the blades **204** of the rotor assembly **202** or **301**. Once the blades **204** start rotating, the blades **204** of the rotor assembly **202** or **301** continue to rotate at a speed proportional to the wind speed due to the force of wind on the blades **204** and the electrical energy produced by the photovoltaic cells **206**. Furthermore, the rotation of the rigidly attached solar dome **203** is at speed of, for example, about 10 revolutions per minute (rpm) to about 1000 rpm, which cools the photovoltaic cells **206** housed in the solar dome **203** and decreases the temperature increase of the photovoltaic cells **206**, thereby increasing the power generation efficiency of the photovoltaic cells **206**.

**[0019]** Under high temperature conditions, cooling the photovoltaic cells **206** increases power output of the photovoltaic cells **206**. The overall efficiency of the solar powered wind turbine apparatus **200** or **300** depends on the rotation of the rotor assembly **202** or **301** and the resultant lowering of temperature of the photovoltaic cells **206**. The high speed rotation of the rotor assembly **202** or **301** cools the photovoltaic cells **206** housed in the solar dome **203**. The rotation of the rotor assembly **202** or **301** circulates ambient air around the photovoltaic cells **206** housed in the solar dome **203** and lowers the temperature of the photovoltaic cells **206**, which minimizes heat build-up in the photovoltaic cells **206** and prevents over heating of the photovoltaic cells **206**, thereby allowing the photovoltaic cells **206** to operate more efficiently and generate more electrical energy or electric power. Due to the lowered temperature of the photovoltaic cells **206**, an increased number of photons from the solar energy of incident sunlight are absorbed by the photovoltaic cells **206**, thereby dislodging an increased number of electrons from the atoms of the semiconductor material. These electrons then flow toward the front surface of the photovoltaic cells **206**. The lowered operating temperature of the photovoltaic cells **206** facilitates better flow of electrons on the front surface of the photovoltaic cells **206**, thereby increasing the amount of electrical energy output of the photovoltaic cells **206**. The continuous rotation of the rotor assembly **202** or **301** at high rpm generates a high velocity air flow over the surface of the photovoltaic cells **206** and keeps dust and other materials from the environment from depositing and building up on the surface of the photovoltaic cells **206**, thereby increasing the efficiency of the photovoltaic cells **206**. In an embodiment, the wind energy and the solar powered rotational energy from the electric motor **215** or **306** together increase output power of the solar powered wind turbine apparatus **200** or **300**.

**[0020]** FIG. **2A** exemplarily illustrates a partial side elevation view of a solar powered horizontal axis wind turbine apparatus **200** for reducing or eliminating wind cut-in speed. The solar powered horizontal axis wind turbine apparatus **200** disclosed herein comprises a frame **218** exemplarily illustrated in FIG. **2B**, the rotor assembly **202**, the solar dome **203** with photovoltaic cells **206**, and an electric motor **215**. The electric motor **215** of the solar powered horizontal axis wind turbine apparatus **200** has a body **216** and a shaft **217** as exemplarily illustrated in FIG. **2B**. The electric motor **215** is, for example, a direct current (DC) motor. The electric motor **215** is electrically connected to the photovoltaic cells **206**. The body **216** of the electric motor **215** is rigidly connected to the closed end **203a** of the solar dome **203** of the rotor assembly **202** as exemplarily illustrated in FIG.

**2B**. The shaft **217** of the electric motor **215** extends from the body **216** of the electric motor **215** and is rigidly connected to the stationary axle **201** of the frame **218**. In an embodiment, the shaft **217** of the electric motor **215** is fixed. The body **216** of the electric motor **215** is rotatable about the shaft **217** of the electric motor **215**. The electric motor **215** receives electrical energy from the photovoltaic cells **206** rigidly attached on the solar dome **203** and/or on the blades **204** of the rotor assembly **202**. The electric motor **215** rotates the rotor assembly **202** about a horizontal axis X-X **207** of the stationary axle **201** of the frame **218** on receiving electrical energy produced by the photovoltaic cells **206**. The rotor assembly **202** is configured to rotate about the horizontal axis X-X **207** in response to a force of wind on the blades **204** and the powered electric motor **215**.

**[0021]** In an embodiment, the solar powered horizontal axis wind turbine apparatus **200** further comprises a first drive mechanism **205** encircling the blades **204** of the rotor assembly **202**, and an electric generator **208** as exemplarily illustrated in FIG. **2A**. The electric generator **208** is engageably connected to the rotor assembly **202** via the first drive mechanism **205**. The first drive mechanism **205** is rigidly attached to the blades **204** of the rotor assembly **202**. The blades **204** of the rotor assembly **202** are rigidly connected to a periphery **203b** of the solar dome **203** exemplarily illustrated in FIG. **2B**, and are encircled by the first drive mechanism **205**. The blades **204** extend radially from the solar dome **203**. The first drive mechanism **205** that encircles the blades **204** of the rotor assembly **202** engageably communicates with a second drive mechanism **209** rigidly connected to the electric generator **208**. For example, a gear ring **205a** encircling the blades **204** is in engageable communication with a gear ring **209a** rigidly connected to the electric generator **208**. The gear ring **205a** rigidly connected to the rotor assembly **202** engageably communicates with the gear ring **209a** rigidly connected to the electric generator **208** for transferring mechanical energy produced by the rotation of the rotor assembly **202** to the electric generator **208**. The electric generator **208** converts the mechanical energy produced by the rotor assembly **202** into electrical energy.

**[0022]** In an embodiment, the solar powered horizontal axis wind turbine apparatus **200** comprises one or more energy storage devices **212a** and **212b** in electric communication with the photovoltaic cells **206** on the solar dome **203** of the rotor assembly **202** and the electric generator **208**. The electric generator **208** is electrically connected to the energy storage devices **212a** and **212b**. The energy storage devices **212a** and **212b** store the electrical energy produced by the photovoltaic cells **206** and the electric generator **208**. The stored electrical energy is used for multiple purposes, for example, providing power to the electric motor **215** to rotate the blades **204** of the solar powered horizontal axis wind turbine apparatus **200**. The stored electrical energy activates the electric motor **215** by powering the electric motor **215** to rotate the blades **204** of the rotor assembly **202** when there is minimal or no wind in the vicinity of the solar powered horizontal axis wind turbine apparatus **200**. The stored electrical energy also supports the rotation of the blades **204** of the rotor assembly **202** by powering the electric motor **215** when the wind speed is at a wind speed level between a cut-in speed and a cut-out speed. As used herein, “cut-out speed” refers to the highest wind speed at which a wind turbine stops producing power. The stored electrical energy also enables a uniform and continuous power output of the solar powered horizontal axis wind turbine apparatus **200**.

**[0023]** In an embodiment, the solar powered horizontal axis wind turbine apparatus **200** disclosed herein further comprises a switch **213** in electric communication with the photovoltaic cells **206**, the electric motor **215**, and the energy storage devices **212a** and **212b**. The switch **213** is used to break an electrical circuit formed by the photovoltaic cells **206**, the electric motor **215**, and the energy storage devices **212a** and **212b** for interrupting the electrical energy, for example, current, or for diverting the electrical energy from the photovoltaic cells **206** to the energy storage devices **212a** and **212b** or from the energy storage devices **212a** and **212b** to the electric motor **215**. The switch **213** is configured to transfer the electrical energy produced by the photovoltaic cells **206** to the electric motor **215** and/or the energy storage devices **212a** and **212b**. The electrical energy stored in one energy storage device, for example, **212a** powers the electric motor **215** for rotating the rotor assembly **202**, while the electrical energy stored in another energy storage device, for example, **212b** is transferred to one or more external energy stations. In an example, the energy storage device **212a** transfers the stored electrical energy to the electric motor **215**, for example, during nighttime. The energy storage device **212b** provides power to other energy stations, for example, a power grid, a substation, etc. In an embodiment, the switch **213** electrically disconnects the photovoltaic cells **206** from the electric motor **215** and transfers the electrical energy produced by the photovoltaic cells **206** to the energy storage devices **212a** and **212b**. In this embodiment, the rotation of the blades **204** of the rotor assembly **202** is continued by the force of wind on the blades **204** of the rotor assembly **202** after the electrical disconnection of the photovoltaic cells **206** from the electric motor **215**.

**[0024]** In the presence of sunlight, the switch **213** may be configured to transfer the electrical energy produced by the photovoltaic cells **206** to the electric motor **215** and also to the energy storage devices **212a** and **212b**, thereby charging the energy storage devices **212a** and **212b**. In the absence of sunlight, the switch **213** may be configured to transfer the electrical energy stored in the charged energy storage devices **212a** and **212b** to the electric motor **215** to provide a turning moment to the rotor assembly **202**. Subsequently, the charged energy storage devices **212a** and **212b** may continue to remain connected or may be disconnected from the electric motor **215** as desired by a user depending on parameters such as prevailing wind speed, energy output from the solar powered horizontal axis wind turbine apparatus **200**, various other applications such as lighting, heating, etc., for which electrical energy is used.

**[0025]** In an embodiment, the solar powered horizontal axis wind turbine apparatus **200** disclosed herein further comprises a slip ring **210** connected to the photovoltaic cells **206** and in electric communication with the photovoltaic cells **206** to allow a continuous transfer of the electrical energy from the photovoltaic cells **206** to the energy storage devices **212a** and **212b**. The slip ring **210** is disposed on the stationary axle **201** of the frame **218** connected to the rotor assembly **202**. The slip ring **210** transfers the electrical energy produced by the photovoltaic cells **206** to the energy storage devices **212a** and **212b** for storage of the electrical energy.

**[0026]** In an embodiment, the solar powered horizontal axis wind turbine apparatus **200** disclosed herein further comprises a diode **211** electrically connected between the electric generator **208** and one energy storage device, for example, **212a** for conducting electrical energy in only one direction, that is, from the electric generator **208** to the energy storage device **212a**. The diode **211** prevents the electrical energy from being transferred back to the electric generator **208** from the energy storage device **212a**.

**[0027]** During operation of the solar powered horizontal axis wind turbine apparatus **200**, when the rotor assembly **202** housing the photovoltaic cells **206** rotates, the slip ring **210** mounted on the stationary axle **201** facilitates transfer of electrical energy from the photovoltaic cells **206** to the electric motor **215** and/or to the energy storage devices **212a** and **212b**. When the rotor assembly **202** is stationary, the electrical energy that is available in one of the energy storage devices **212a** and **212b** is transferred to the electric motor **215**. Therefore, the solar powered horizontal axis wind turbine apparatus **200** disclosed herein facilitates bidirectional transfer of power from the photovoltaic cells **206** to the energy storage devices **212a** and **212b** via the slip ring **210** when the rotor assembly **202** housing the photovoltaic cells **206** rotates continuously, and from the energy storage devices **212a** and **212b** to the electric motor **215** when the rotor assembly **202** is stationary. The solar powered horizontal axis wind turbine apparatus **200** disclosed herein regulates the electrical energy to flow in a direction to serve the requirements of a user. For example, electrical energy flows from the photovoltaic cells **206** to the electric motor **215**, or from the energy storage devices **212a** and **212b** to the electric motor **215**, or from the photovoltaic cells **206** to the energy storage devices **212a** and **212b**, for example, by the switch **213**, the diode **211**, etc.

**[0028]** In an embodiment, one or more wind sensors **214** are operably disposed on one or more blades **204** of the rotor assembly **202** for monitoring data of the force of wind. A wind sensor **214** disposed on one of the blades **204** of the rotor assembly **202** is exemplarily illustrated in FIG. **2A**. The wind sensors **214** measure the wind's speed and pressure. The wind sensors **214** gauge the speed of wind and ensure that the solar dome **203** of the rotor assembly **202** is rotated by the electric motor **215** only when the wind speed is slow and/or minimal. For example, if the wind speed is substantially less than the cut-in speed to generate the rotational motion in the blades **204** of the rotor assembly

**202**, the wind sensor **214** detects the reduction in the wind speed and starts the electric motor **215** powered by the photovoltaic cells **206** to rotate the blades **204** until the wind speed increases to a magnitude which can sustain a continuous rotation of the blades **204** of the rotor assembly **202**.

**[0029]** FIG. **2B** exemplarily illustrates a partial sectional view of the solar powered horizontal axis wind turbine apparatus **200**, showing the electric motor **215** and the frame **218**. The frame **218** supports the rotor assembly **202**. In an embodiment, the frame **218** comprises a vertical tower **219** and the stationary axle **201**. The stationary axle **201**, having a first end **201a** and a second end **201b**, is perpendicularly connected to the vertical tower **219**. The second end **201b** of the stationary axle **201** is rigidly connected to the vertical tower **219**. The rotor assembly **202** of the solar powered horizontal axis wind turbine apparatus **200** is rotatably connected to the frame **218** and rotates in response to a force of wind and the electric motor **215**.

**[0030]** The rotor assembly **202** is rotatably connected to the first end **201a** of the stationary axle **201** of the frame **218**, for example, via one or more bearings **220**. The solar dome **203** is rigidly connected to the first end **201a** of the stationary axle **201** of the frame **218**. In an embodiment, an anemometer **221** is operably connected to the frame **218** for measuring wind speed. In another embodiment, a tachometer **222** is operably connected to the frame **218** for measuring the speed of rotation of the rotor assembly **202**. In an embodiment, the solar powered horizontal axis wind turbine apparatus **200** disclosed herein further comprises a weatherproof seal **223** that encapsulates the photovoltaic cells **206** on the solar dome **203** of the rotor assembly **202** for protecting the photovoltaic cells **206** from water and weather conditions.

**[0031]** The photovoltaic cells **206** are attached to the solar dome **203** by positioning adjacent photovoltaic cells **206** behind the weatherproof seal **223**. In an embodiment, the weatherproof seal **223** is further configured to fixedly attach adjacent photovoltaic cells **206** in position on the solar dome **203** to prevent the photovoltaic cells **206** from being dislodged from the solar dome **203**. As exemplarily illustrated in FIG. **2B**, the electric motor **215** is axially positioned within the solar dome **203**. The shaft **217** of the electric motor **215** extends from the body **216** of the electric motor **215** through the stationary axle **201** of the frame **218**. In an embodiment, the shaft **217** is operably connected to the blades **204** of the rotor assembly **202** at a hub section **204a** of the blades **204**. The photovoltaic cells **206** are in electrical communication with the electric motor **215** via wires **225**. The electrical energy generated in the photovoltaic cells **206** from exposure to incident sunlight is transferred to the electric motor **215** through the wires **225**. The transferred electrical energy actuates the electric motor **215**, thereby driving the body **216** of the electric motor **215** about the fixed shaft **217**. Therefore, the blades **204** of the rotor assembly **202** rotate due to the rotation of the body **216** about the shaft **217** of the electric motor **215** and reduces or eliminates the cut-in speed required to rotate the blades **204** of the rotor assembly **202**.

**[0032]** In an optional embodiment, the solar powered horizontal axis wind turbine apparatus **200** disclosed herein further comprises one or more flywheels **224** geared with each other and operably connected to the electric motor **215**. One of the flywheels **224** is configured to be removably and operably connected to the shaft **217** of the electric motor **215** to provide a continuous momentum of rotation for the blades **204** of the rotor assembly **202**.

**[0033]** FIG. **3A** exemplarily illustrates a front elevation view of a solar powered vertical axis wind turbine apparatus **300** for reducing or eliminating wind cut-in speed. The solar powered vertical axis wind turbine apparatus **300** disclosed herein comprises the rotor assembly **301**, a vertical axle **304**, the solar dome **203** with the photovoltaic cells **206**, and a first drive mechanism **303**. The rotor assembly **301** is configured to rotate in a direction, for example, a clockwise direction or a counterclockwise direction, along a vertical axis Y-Y **302** of the rotor assembly **301** in response to a force of wind directed against blades **204**. Rotation of the rotor assembly **301** produces mechanical energy. In an embodiment as exemplarily illustrated in FIG. **3A**, the rotor assembly **301** is of a generally cylindrical shape. Alternatively, the rotor assembly **301** is, for example, of a conical shape or a bulged cylindrical shape. As exemplarily illustrated in FIG. **3A**, the rotor assembly **301** comprises a closed upper end **301a**, an open lower end **301b**, and a side wall **301c** defined between the closed upper end **301a** and the open lower end **301b**. The side wall **301c** of the rotor assembly **301** is, for example, a cylindrical wall for the rotor assembly **301** of a cylindrical shape as exemplarily illustrated in FIG. **3A**. The vertical axle **304** of the solar powered vertical axis wind turbine apparatus **300** disclosed herein is coaxially positioned within the rotor assembly **301** along the vertical axis Y-Y **302** of the rotor assembly **301**.

**[0034]** In an embodiment, the rotor assembly **301** comprises the blades **204** configured on the side wall **301c** of the rotor assembly **301**. The rotor assembly **301** rotates about the vertical axis Y-Y **302** in response to the force of wind on the blades **204** and a powered electric motor **306** exemplarily illustrated in FIG. **3B**. In an embodiment as exemplarily illustrated in FIG. **3A**, the blades **204** are defined along the side wall **301c** of the rotor assembly **301**. Each of the blades **204** is of a predetermined shape, for example, a tear drop shape, a spade shape, a curved shape, etc., and is arranged adjacent to each other on the side wall **301c** about the vertical axle **304**. Each of the blades **204** provided on the side wall **301c** of the rotor assembly **301** has, for example, a straight profile, a curved profile, or a curvilinear profile for increasing the surface area of exposure of the rotor assembly **301** to the force of wind to increase the speed of rotation of the rotor assembly **301**. In an embodiment as exemplarily illustrated in FIG. **3A**, the solar dome **203** that accommodates the photovoltaic cells **206** is positioned on the closed upper end **301a** of the rotor assembly **301**.

**[0035]** The solar dome **203** with the photovoltaic cells **206** of the solar powered vertical axis wind turbine apparatus **300** disclosed herein are rigidly attached to the closed upper end **301a** of the rotor assembly **301**. In an embodiment as exemplarily illustrated in FIG. **3A**, the solar dome **203** accommodating the rigidly attached photovoltaic cells **206** extends beyond a periphery **301d** of the closed upper end **301a** of the rotor assembly **301**. In this embodiment, the diameter of the first drive mechanism **303** of the rotor assembly **301** extends beyond the diameter of the solar dome **203**. In another embodiment, the solar dome **203** is positioned on the closed upper end **301a** of the rotor assembly **301** and contained within the periphery **301d** of the closed upper end **301a** of the rotor assembly **301**. The photovoltaic cells **206** receive solar energy from incident sunlight and convert the received solar energy into electrical energy.

**[0036]** The first drive mechanism **303** of the solar powered vertical axis wind turbine apparatus **300** disclosed herein is rigidly connected around the side wall **301c** of the rotor assembly **301** at the open lower end **301b** of the rotor assembly **301**. In an embodiment as exemplarily illustrated in FIG. **3A**, the first drive mechanism **303** of the rotor assembly **301** is a gear ring **303a** rigidly connected around the side wall **301c** of the rotor assembly **301**.

**[0037]** In an embodiment, the solar powered vertical axis wind turbine apparatus **300** disclosed herein further comprises an electric generator **208**. The electric generator **208** is rotatably connected to the rotor assembly **301** via the first drive mechanism **303**. The electric generator **208** comprising the second drive mechanism **305** is in engageable communication with the first drive mechanism **303** on the rotor assembly **301**. The first drive mechanism **303** on the rotor assembly **301** engageably communicates with the second drive mechanism **305** of the electric generator **208** for transferring the mechanical energy produced by the rotation of the rotor assembly **301** to the electric generator **208**. For example, the gear ring **303a** of the rotor assembly **301** engageably communicates with the gear ring **305a** of the electric generator **208** for transferring mechanical energy produced by the rotation of the rotor assembly **301** to the electric generator **208**. The electric generator **208** converts mechanical energy produced by the rotation of the rotor assembly **301** into electrical energy. The solar powered vertical axis wind turbine apparatus **300** disclosed herein thereby produces energy in response to the force of wind directed against the blades **204** and the electrical energy from the photovoltaic cells **206** and the electric generator **208**.

**[0038]** In an embodiment as exemplarily illustrated in FIG. **3A**, the electric generator **208** is positioned in an upright position below the rotor assembly **301**. In another embodiment, the electric generator **208** is positioned in an inverted position alongside the rotor assembly **301**. In this embodiment, the second drive mechanism **305** of the electric generator **208** is configured to engageably connect to the first drive mechanism **303** of the rotor assembly **301** with sufficient clearance between the electric generator **208** and the rotor assembly **301**. For example, the diameter of the second drive mechanism **305** of the electric generator **208** is extended beyond the diameter of the electric generator **208**.

**[0039]** FIG. **3B** exemplarily illustrates a partial cut-away front sectional view of an embodiment of the solar powered vertical axis wind turbine apparatus **300**, showing the electric motor **306**. The electric motor **306** is connected to and is in electric communication with the photovoltaic cells **206** rigidly attached to the solar dome **203**. The solar dome **203** is positioned on the closed upper end **301a** of the rotor assembly **301**. The electric motor **306** is coaxially disposed below the photovoltaic cells **206**. In this embodiment, the solar powered vertical axis wind turbine apparatus **300** disclosed herein further comprises a spiral groove **309** defined along an inner surface **301e** of a truncated cone **312** of the rotor assembly **301**. The rotor assembly **301** rotates about the vertical axis Y-Y **302** in response to a force of thermal updraft of air flow against the spiral groove **309**. The thermal updraft of air is caused as a result of convection of hot air relative to cold air from the atmosphere. Hot air from below the open lower end **301b** of the rotor assembly **301** replaces the cold air within the rotor assembly **301**. This replacement of the cold air by the hot air gives rise to convection currents that appear as the thermal updraft of air. The thermal updraft of air enters the rotor assembly **301** through the open lower end **301b** of the rotor assembly **301** and is directed against the spiral groove **309** for rotating the rotor assembly **301**.

**[0040]** The air that enters into the rotor assembly **301** from the open lower end **301b** of the rotor assembly **301** is exemplarily illustrated by curved arrows **313**. The thermal updraft of the air that flows against the spiral groove **309** within the rotor assembly **301** is exemplarily illustrated by curved arrows **314**. The air flow against the spiral groove **309** in turn rotates the rotor assembly **301**.

[0041] The photovoltaic cells **206** capture solar energy from sunlight and convert the captured solar energy into electrical energy. The photovoltaic cells **206** transfer the electrical energy to the electric motor **306** to power the electric motor **306**. The electric motor **306** rotates on receiving the electrical energy and rotates the rotor assembly **301**. In this embodiment, the vertical axle **304** of the solar powered vertical axis wind turbine apparatus **300** is rigidly connected to the shaft **307** of the electric motor **306** and coaxially positioned within the rotor assembly **301** along the vertical axis Y-Y **302** of the rotor assembly **301**. The rotor assembly **301** is rotatably connected to the vertical axle **304**, for example, by the bearings **308a**, a sleeve **308b**, etc., to enable rotation of the rotor assembly **301** relative to the vertical axle **304**. The electric motor **306** powered by the photovoltaic cells **206** on the solar dome **203** provides the initial power to initiate the rotation of the blades **204** of the rotor assembly **301** when the speed of wind is less than the cut-in speed, thereby reducing or eliminating the cut-in speed required to rotate the blades **204** of the rotor assembly **301**.

[0042] In an embodiment, the solar powered vertical axis wind turbine apparatus **300** disclosed herein further comprises an energy storage device **212a** electrically connected to the photovoltaic cells **206** and the electric generator **208**. The energy storage device **212a** stores the electrical energy output from the photovoltaic cells **206** and the electric generator **208**. The electrical energy stored in the energy storage device **212a** can be used to kick start and rotate the blades **204** of the rotor assembly **301** when there is minimal or no wind in the vicinity of the solar powered vertical axis wind turbine apparatus **300**.

[0043] In an embodiment, the solar powered vertical axis wind turbine apparatus **300** disclosed herein further comprises a slip ring **310** positioned on the shaft **307** of the electric motor **306**. The slip ring **310** enables the photovoltaic cells **206** to transmit the electrical energy to the energy storage device **212a** when the electric motor **306** is electrically disconnected from the photovoltaic cells **206** via a switch **311**. The slip ring **310** enables the photovoltaic cells **206** to execute continuous rotations of the rotor assembly **301** while electrical energy is continuously transferred from the photovoltaic cells **206** to the energy storage device **212a** via the slip ring **310**. The rotor assembly **301** continues to rotate even after the electrical disconnection of the electric motor **306** and the photovoltaic cells **206** by the switch **311**. Meanwhile, the electrical energy of the photovoltaic cells **206** is also concurrently transferred to the energy storage device **212a**.

**[0044]** Consider an example where the solar powered vertical axis wind turbine apparatus **300** is utilized. The photovoltaic cells **206** disposed on the closed upper end **301a** of the rotor assembly **301** receive solar energy from sunlight and convert the solar energy into electrical energy. The electrical energy of the photovoltaic cells **206** is transferred to the electric motor **306** and causes the electric motor **306** to rotate about its shaft **307** rigidly connected to the vertical axle **304** within the rotor assembly **301**. The electric motor **306** further rotates the rotor assembly **301**. The electric motor **306** powered by the photovoltaic cells **206** on the solar dome **203** provides the initial start up speed for rotating the blades **204** of the rotor assembly **301** and therefore reduces or eliminates the cut-in speed required to rotate the blades **204** of the rotor assembly **301**. Furthermore, wind impinges on the blades **204** on the rotor assembly **301**. The force of wind against the blades **204** continues the rotation of the rotor assembly **301**. The thermal updraft of air flow causes a spinning effect of the rotor assembly **301** caused by the upward air flow impinging and moving along the spiral groove **309** defined along the inner surface **301e** of the rotor assembly **301**. This spinning effect also causes the rotor assembly **301** to rotate about the vertical axle **304** on which the rotor assembly **301** is rotatably connected. The rotation of the rotor assembly **301** rotates the electric generator **208** that is rotatably connected to the first drive mechanism **303** of the rotor assembly **301** via its drive mechanism **305**. The electric generator **208** converts the mechanical energy of the rotor assembly **301** into electrical energy. The solar powered vertical axis wind turbine apparatus **300** disclosed herein thereby produces energy.

**[0045]** The solar powered horizontal axis wind turbine apparatus **200** exemplarily illustrated in FIGS. **2A-2B** and the solar powered vertical axis wind turbine apparatus **300** exemplarily illustrated in FIGS. **3A-3B**, each require a different method for mounting the solar dome **203**. The electric motor **215** or **306** powered by the photovoltaic cells **206** on the solar dome **203** provide the initial start up power for the solar powered wind turbine apparatus **200** or **300**. In this case, the shaft **217** or **307** of the electric motor **215** or **306** is fixed. Once the rotor assembly **202** or **301** starts to rotate, the wind speed continuously rotates the rotor assembly **202** or **301**. The additional energy provided by the photovoltaic cells **206** in the solar dome **203** can also be stored in an energy storage device, for example, **212a** that is in electric communication with the photovoltaic cells **206** on the solar dome **203** and/or used for other purposes.

**[0046]** FIG. **4** exemplarily illustrates a graphical representation of power output of the solar powered wind turbine apparatus **200** or **300** exemplarily illustrated in FIGS. **2A-2B** and FIGS. **3A-3B**, powered by wind energy and solar energy. The solar powered horizontal axis wind turbine apparatus **200** exemplarily illustrated in FIGS. **2A-2B**, or the solar powered vertical axis wind turbine apparatus **300** exemplarily illustrated in FIGS. **3A-3B** is a hybrid solar and wind turbine. At any given point of time, due to the position of the sun during the day, actual solar energy output from incident sunlight changes based on the radiation of the sun. Unused solar energy received from the sun is transferred and stored in one or more energy storage devices, for example, **212a**, **212b**, etc., exemplarily illustrated in FIG. **2A** and FIG. **3B**, in the form of electrical energy. The stored electrical energy can be recycled and used by the solar powered wind turbine apparatus **200** or **300** when wind speed drops below the cut-in speed, or when the wind speed is in between the cut-in speed and the cut-out speed.

**[0047]** As exemplarily illustrated in FIG. **4**, solar energy acts as a primary driving force for power generation by the solar powered wind turbine apparatus **200** or **300** for up to about 4 meters/second (m/s) of wind speed. Once the wind speed reaches to about 12 m/s, the total power output contributed by the wind energy typically remains flat, irrespective of the wind as exemplarily illustrated in FIG. **4**. The difference of the gradually reducing contribution of the solar energy in power generation can be transferred to the energy storage devices, for example, **212a**, **212b**, etc.

**[0048]** The foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention disclosed herein. While the invention has been described with reference to various embodiments, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Further, although the invention has been described herein with reference to particular means, materials, and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather, the invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims. Those skilled in the art, having the benefit of the teachings of this specification, may effect numerous modifications thereto and changes may be made without departing from the scope and spirit of the invention in its aspects.

CLAIMS

I claim:

1. A method for initiating rotation of blades of a wind turbine when a speed of wind is less than a cut-in speed, said method comprising:

providing a solar powered wind turbine apparatus comprising:

a rotor assembly comprising a plurality of said blades;

a solar dome operably connected to said rotor assembly, said solar dome configured to house and support an interconnected assembly of photovoltaic cells on a surface of said solar dome; and

an electric motor electrically connected to said photovoltaic cells housed in said solar dome, said electric motor powered by said photovoltaic cells to initiate said rotation of said blades of said rotor assembly when said speed of said wind is less than said cut-in speed;

receiving solar energy from incident sunlight by said photovoltaic cells of said solar powered wind turbine apparatus;

converting said received solar energy from said incident sunlight on said photovoltaic cells into electrical energy by said photovoltaic cells;

transferring said electrical energy produced by said photovoltaic cells to said electric motor of said solar powered wind turbine apparatus; and

rotating said blades of said rotor assembly of said solar powered wind turbine apparatus by said electric motor using said electrical energy transferred by said photovoltaic cells, thereby one of reducing and eliminating said cut-in speed required for said rotation of said blades.

2. The method of claim 1, further comprising storing said electrical energy produced by said photovoltaic cells in one or more energy storage devices, wherein said one or more energy storage devices are in electric communication with said photovoltaic cells on said solar dome of said rotor assembly, wherein said stored electrical energy is configured to one of activate said electric motor by powering said electric motor to rotate said blades of said rotor assembly when there is no said wind, and support said rotation of said blades of said rotor assembly by powering said electric motor when said speed of said wind is at a level between said cut-in speed and a cut-out speed.

3. The method of claim 2, further comprising electrically disconnecting said photovoltaic cells from said electric motor by a switch in electric communication with said photovoltaic cells, said electric motor, and said one or more energy storage devices, wherein said switch is configured to break an electrical circuit formed by said photovoltaic cells, said electric motor, and said one or more energy storage devices to interrupt said electrical energy and transfer said electrical energy produced by said photovoltaic cells to said one or more energy storage devices.

4. The method of claim 3, wherein said rotation of said blades of said rotor assembly is further continued by a force of said wind on said blades of said rotor assembly after said electrical disconnection of said photovoltaic cells from said electric motor.

5. The method of claim 1, further comprising engageably connecting an electric generator to said rotor assembly via a first drive mechanism, wherein said first drive mechanism connected to said rotor assembly is in engageable communication with a second drive mechanism rigidly connected to said electric generator, and wherein said electric generator is configured to convert mechanical energy produced by said rotor assembly to additional electrical energy.

6. The method of claim 5, further comprising electrically connecting said electric generator to one or more energy storage devices, wherein said one or more energy storage devices are configured to store said additional electrical energy produced by said electric generator, and wherein said stored additional electrical energy is configured to one of activate said electric motor by powering said electric motor to rotate said blades of said rotor assembly when there is no wind, and support said rotation of said blades of said rotor assembly by powering said electric motor when a speed of said wind is at a level between said cut-in speed and a cut-out speed.

7. A solar powered wind turbine apparatus for reducing or eliminating a cut-in speed, said solar powered wind turbine apparatus comprising:

a rotor assembly comprising a plurality of blades;

a solar dome operably connected to said rotor assembly, said solar dome configured to house and support an interconnected assembly of photovoltaic cells on a surface of said solar dome, said photovoltaic cells configured to receive solar energy from incident sunlight, convert said received solar energy into electrical energy, and transfer said electrical energy to an electric motor; and

said electric motor electrically connected to said photovoltaic cells housed in said solar dome, said electric motor configured to be powered by said photovoltaic cells to initiate a rotation of said blades of said rotor assembly using said electrical energy transferred by said photovoltaic cells, when a speed of wind is less than said cut-in speed, thereby one of reducing and eliminating said cut-in speed required for said rotation of said blades.

8. The solar powered wind turbine apparatus of claim 7, wherein said solar dome is configured to rotate about one of a horizontal axis and a vertical axis to enable said photovoltaic cells to receive said solar energy from multiple directions of said incident sunlight.

9. The solar powered wind turbine apparatus of claim 7, further comprising one or more energy storage devices in electric communication with said photovoltaic cells on said solar dome of said rotor assembly, wherein said one or more energy storage devices are configured to store said electrical energy produced by said photovoltaic cells, and wherein said stored electrical energy is configured to one of activate said electric motor by powering said electric motor to rotate said blades of said rotor assembly when there is no said wind, and support said rotation of said blades of said rotor assembly by powering said electric motor when said speed of said wind is at a level between said cut-in speed and a cut-out speed.

10. The solar powered wind turbine apparatus of claim 9, further comprising a switch in electric communication with said photovoltaic cells, said electric motor, and said one or more energy storage devices, wherein said switch is configured to break an electrical circuit formed by said photovoltaic cells, said electric motor, and said one or more energy storage devices to interrupt said electrical energy, thereby electrically disconnecting said photovoltaic cells from said electric motor and transferring said electrical energy produced by said photovoltaic cells to said one or more energy storage devices, wherein said rotation of said blades of said rotor assembly is further continued by a force of said wind on said blades of said rotor assembly after said electrical disconnection of said photovoltaic cells from said electric motor.

11. The solar powered wind turbine apparatus of claim 9, further comprising a slip ring disposed on a stationary axle of a frame connected to said rotor assembly, wherein said slip ring is connected to and in electric communication with said photovoltaic cells, and wherein said slip ring is configured to continuously transfer said electrical energy from said photovoltaic cells to said one or more energy storage devices.

12. The solar powered wind turbine apparatus of claim 7, further comprising an electric generator engageably connected to said rotor assembly via a first drive mechanism, wherein said first drive mechanism connected to said rotor assembly is in engageable

communication with a second drive mechanism rigidly connected to said electric generator, and wherein said electric generator is configured to convert mechanical energy produced by said rotor assembly to additional electrical energy.

13. The solar powered wind turbine apparatus of claim 12, wherein said electric generator is electrically connected to one or more energy storage devices, wherein said one or more energy storage devices are configured to store said additional electrical energy produced by said electric generator, and wherein said stored additional electrical energy is configured to one of activate said electric motor by powering said electric motor to rotate said blades of said rotor assembly when there is no wind, and support said rotation of said blades of said rotor assembly by powering said electric motor when a speed of said wind is at a level between said cut-in speed and a cut-out speed.

14. The solar powered wind turbine apparatus of claim 7, further comprising one or more wind sensors operably disposed on one or more of said blades of said rotor assembly, wherein said wind sensors are configured to monitor data of a force of said wind.

15. The solar powered wind turbine apparatus of claim 7, further comprising a weatherproof seal encapsulating said photovoltaic cells on said solar dome of said rotor assembly, wherein said weatherproof seal is configured to protect said photovoltaic cells from water and weather conditions.

16. The solar powered wind turbine apparatus of claim 15, wherein said weatherproof seal is further configured to fixedly attach adjacent said photovoltaic cells in position on said solar dome to prevent said photovoltaic cells from being dislodged from said solar dome.

17. The solar powered wind turbine apparatus of claim 7 configured as a solar powered horizontal axis wind turbine apparatus, wherein said blades of said rotor assembly of said solar powered horizontal axis wind turbine apparatus are configured to extend radially from said solar dome, and wherein said rotor assembly is configured to rotate

about a horizontal axis in response to a force of said wind on said blades and said powered electric motor.

18. The solar powered wind turbine apparatus of claim 7 configured as a solar powered vertical axis wind turbine apparatus, wherein said blades of said rotor assembly of said solar powered vertical axis wind turbine apparatus are configured on a side wall of said rotor assembly, wherein said rotor assembly is configured to rotate about a vertical axis in response to a force of said wind on said blades and said powered electric motor.

19. The solar powered wind turbine apparatus of claim 7, wherein said solar dome accommodating said photovoltaic cells is positioned on an upper end of said rotor assembly.

20. The solar powered wind turbine apparatus of claim 7, further comprising one or more flywheels geared with each other and operably connected to said electric motor, wherein one of said one or more flywheels is configured to be removably and operably connected to a shaft of said electric motor to provide a continuous momentum of rotation for said blades of said rotor assembly.

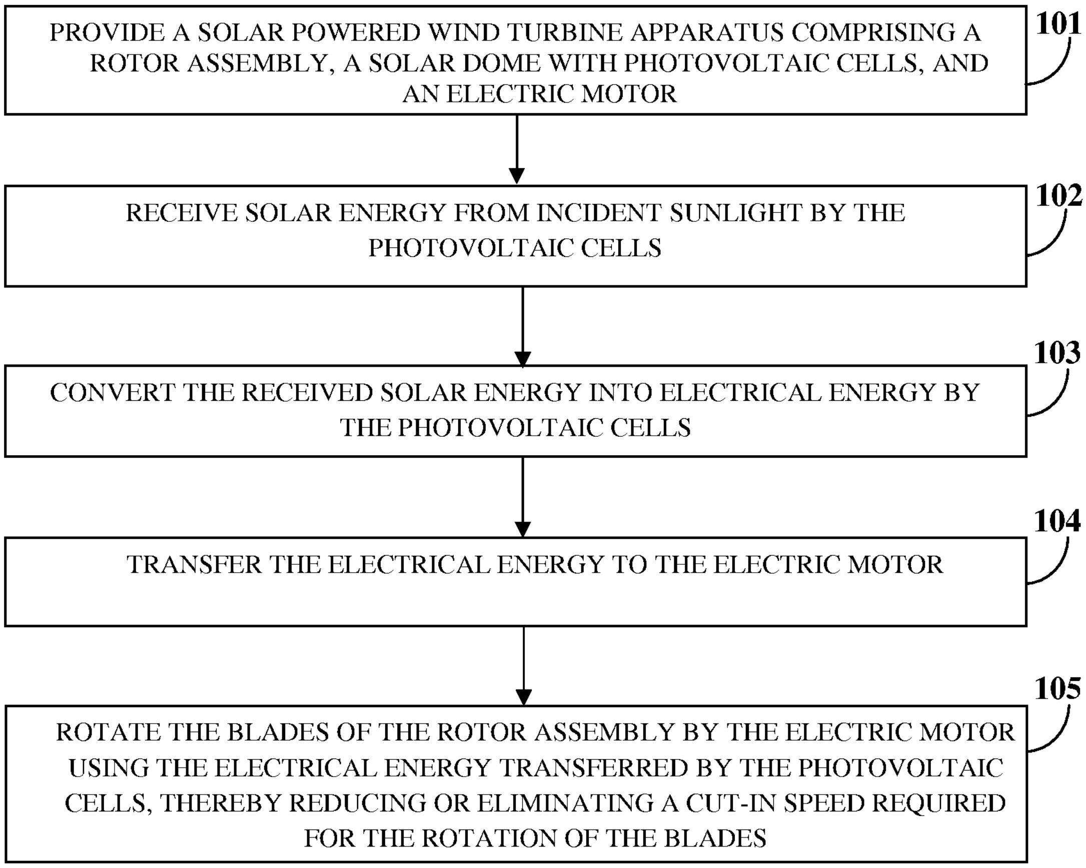
PROVIDE A SOLAR POWERED WIND TURBINE APPARATUS COMPRISING A ROTOR ASSEMBLY, A SOLAR DOME WITH PHOTOVOLTAIC CELLS, AND AN ELECTRIC MOTOR
101
RECEIVE SOLAR ENERGY FROM INCIDENT SUNLIGHT BY THE PHOTOVOLTAIC CELLS
102
CONVERT THE RECEIVED SOLAR ENERGY INTO ELECTRICAL ENERGY BY THE PHOTOVOLTAIC CELLS
103
TRANSFER THE ELECTRICAL ENERGY TO THE ELECTRIC MOTOR
104
ROTATE THE BLADES OF THE ROTOR ASSEMBLY BY THE ELECTRIC MOTOR USING THE ELECTRICAL ENERGY TRANSFERRED BY THE PHOTOVOLTAIC CELLS, THEREBY REDUCING OR ELIMINATING A CUT-IN SPEED REQUIRED FOR THE ROTATION OF THE BLADES
105

**FIG. 1**

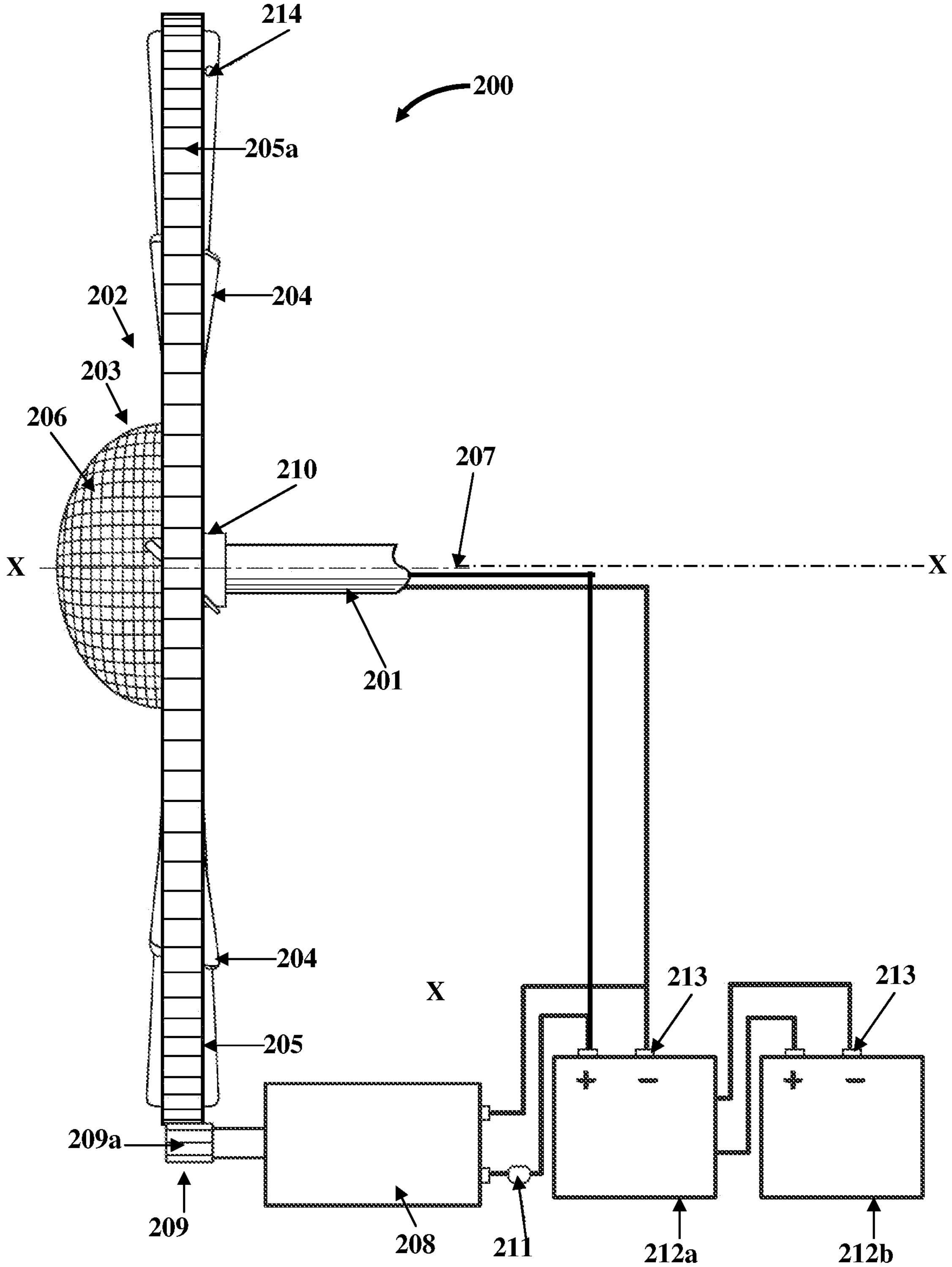
214
200
205a
202
204
203
206
210
207
X
X
201
204
X
213
213
205
209a
209
208
211
212a
212b
+
-
+
-

FIG. 2A

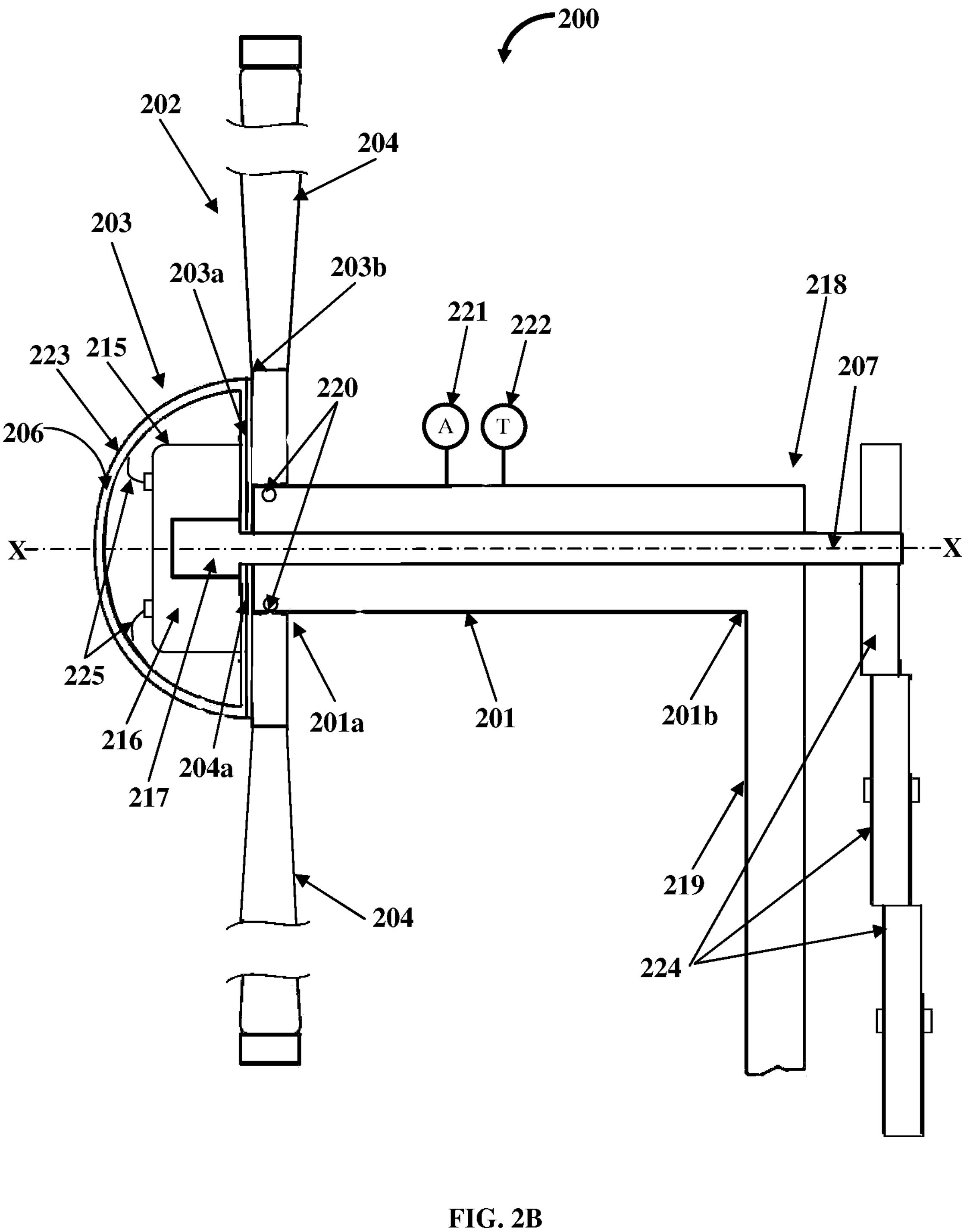
200
202
204
203
203a
203b
221
222
218
223
215
220
207
206
A
T
X
X
225
216
201a
201
201b
217
204a
219
204
224

FIG. 2B

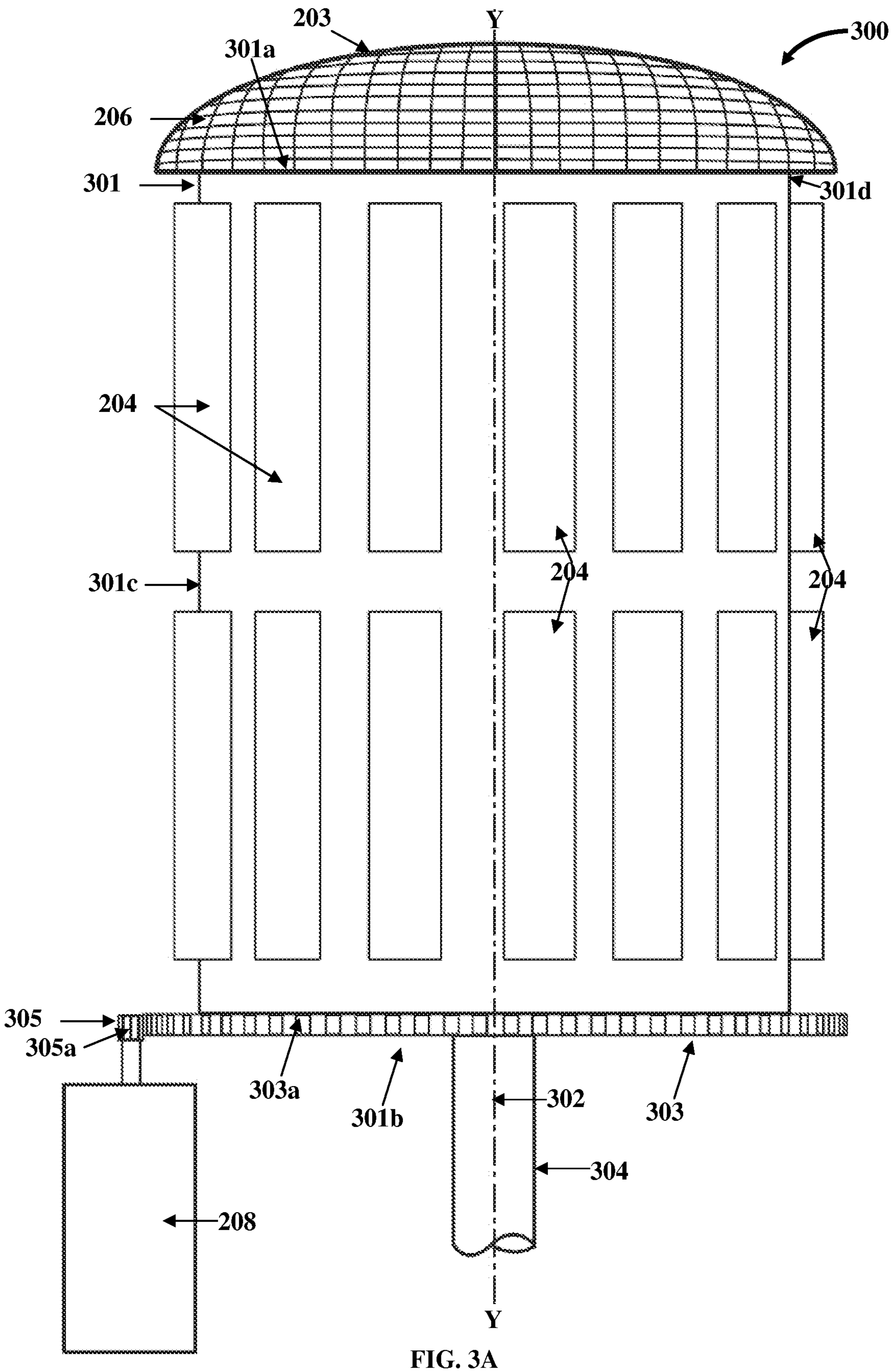
Y
203
300
301a
206
301
301d
204
301c
204
204
305
305a
303a
301b
302
303
304
208
Y

FIG. 3A

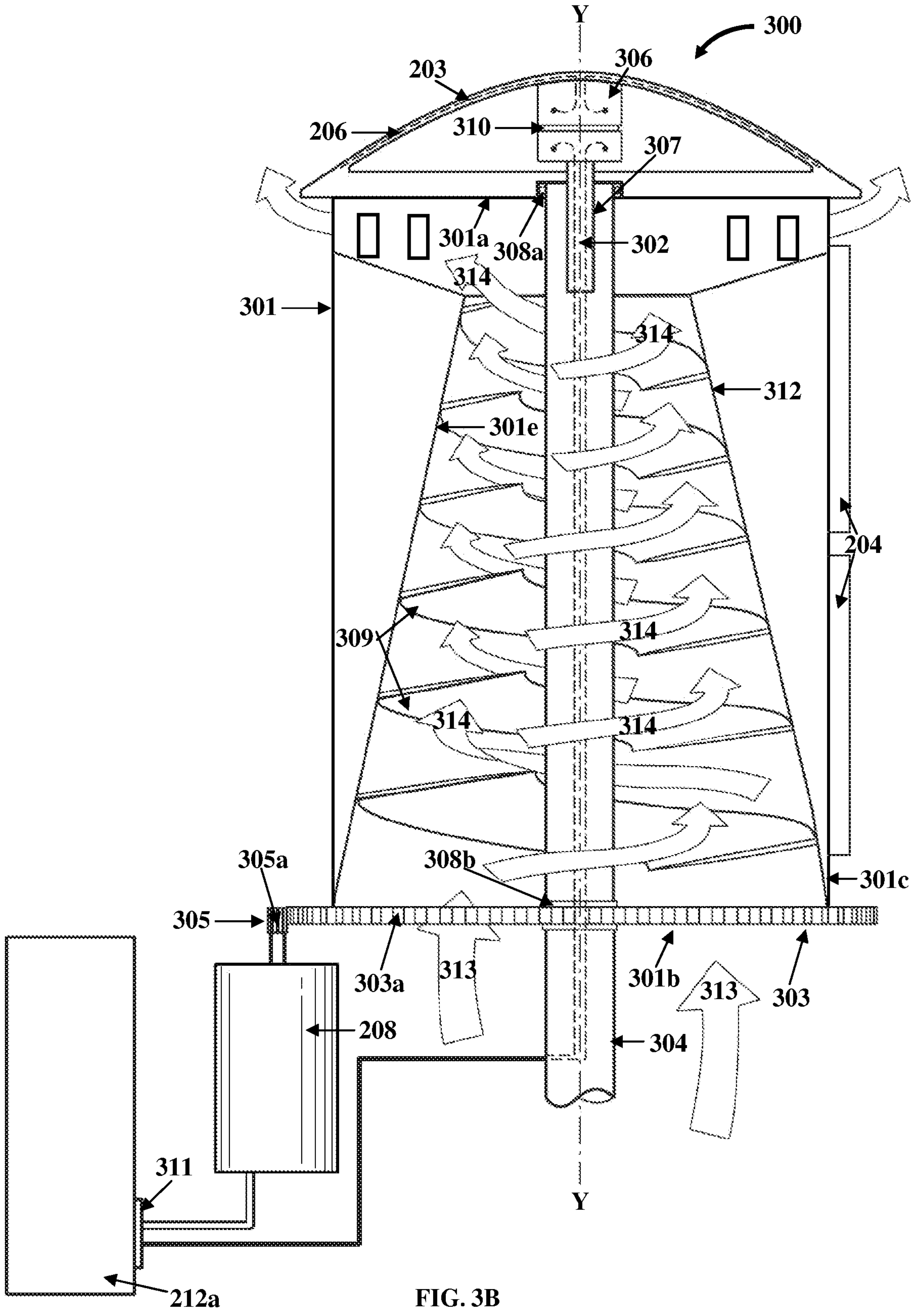
Y
300
203
306
206
310
307
301a
308a
302
314
301
314
312
301e
204
309
314
314
314
314
305a
308b
301c
305
303a
313
301b
313
303
208
304
311
Y
212a

FIG. 3B

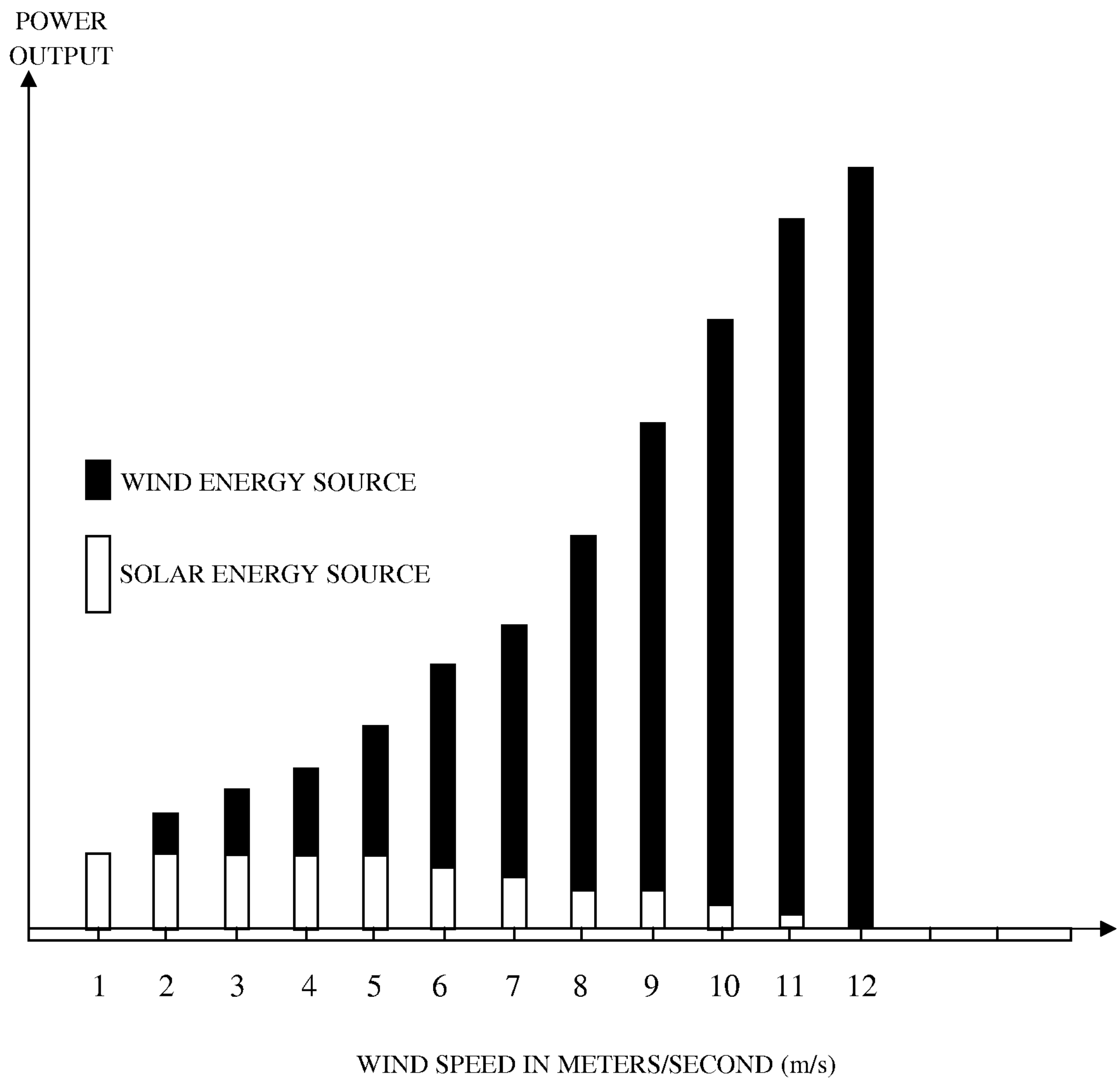
POWER
OUTPUT
WIND ENERGY SOURCE
SOLAR ENERGY SOURCE
1
2
3
4
5
6
7
8
9
10
11
12
WIND SPEED IN METERS/SECOND (m/s)

FIG. 4