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(54) **Title:** A WIND TURBINE AUGMENTED BY A DIFFUSER WITH A VARIABLE GEOMETRY

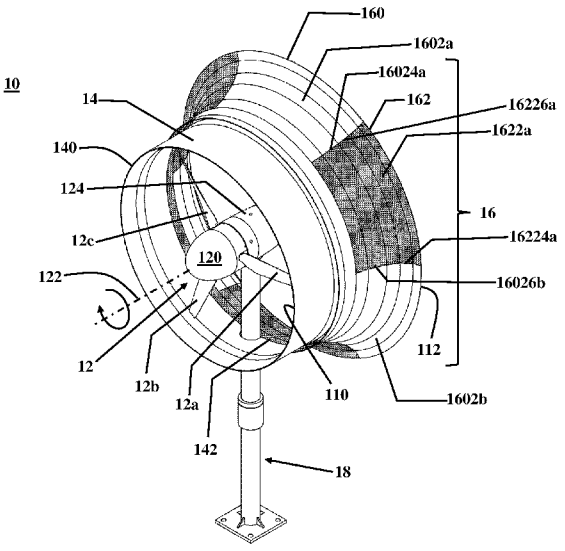


FIG. 1

(57) **Abstract:** A diffuser-augmented wind turbine may include an annular diffuser that may encompass a rotor such that the rotor and the annular diffuser may be coaxial about a main axis. A diffuser-augmented wind turbine may further include a flared diffuser assembly that may be connected to the annular diffuser such that an air stream discharged from the annular diffuser may enter the flared diffuser assembly. A flared diffuser assembly may include a fixed flared diffuser that may include a number of flared petals extending from a leading edge of the fixed flared diffuser toward the trailing edge thereof. A flared diffuser assembly may further include a rotatable flared diffuser that may be disposed coaxially within the fixed flared diffuser and rotatable about the main axis. A rotatable flared diffuser may include a number of flared petals extending from an annular leading edge of the rotatable flared diffuser toward a trailing edge thereof.

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A WIND TURBINE AUGMENTED BY A DIFFUSER WITH A VARIABLE GEOMETRY

TECHNICAL FIELD

[0001] The present disclosure relates to wind turbines augmented by diffusers and particularly relates to a wind turbine augmented by a diffuser with a variable geometry. More particularly, the present disclosure relates to a system and method for controlling the amount of drag forces acting on a diffuser-augmented wind turbine.

BACKGROUND

[0002] A wind turbine converts the power of wind into mechanical power in a rotating shaft of the wind turbine, which may then be connected to an external load. The power generation of a wind turbine may be augmented by mounting a diffuser around the wind turbine. A diffuser, which may be a duct or a set of ducts may increase the wind pressure at the outlet of a wind turbine by decelerating the wind. Such augmentation in power generation of a wind turbine is especially useful when the size of the wind turbine is small, for example, diffusers may be utilized for small portable wind turbines. Although, blades of such small portable wind turbines are smaller in comparison with fixed installations, the augmentation of power generation provided by a diffuser may make up for the decrease in power conversion due to smaller blades.

[0003] Utilizing a properly designed diffuser may allow a wind turbine to reach the Betz-limit and even surpass it. Betz's law states that no turbine can capture more than 59.3% of the kinetic energy in wind. Despite all the advantages, utilizing diffusers in wind turbines may be associated with various negative issues, such as high drag forces working on the diffuser and the diminishing role of the diffuser in the upper range of wind velocities due to a continuous wind velocity speed-up. Drag forces acting on the diffuser may be so high that may lead to the cost of reinforcing the turbine structure overshadow the benefit of energy augmentation of the diffuser. There is, therefore, a need for a method for controlling wind velocity speed-up ratio and the drag force acting on a diffuser of a wind turbine. There is, further a need for a wind turbine augmented with a diffuser, where the size and the shape of the diffuser is controllable to allow for controlling wind velocity speed-up ratio and the drag force acting on the diffuser.

SUMMARY

[0004] This summary is intended to provide an overview of the subject matter of the present disclosure and is not intended to identify essential elements or key elements of the subject matter, nor is it intended to be used to determine the scope of the claimed implementations. The proper scope of the present disclosure may be ascertained from the claims set forth below in view of the detailed description and the drawings.

[0005] According to one or more exemplary embodiments, the present disclosure is directed to an exemplary diffuser-augmented wind turbine. An exemplary diffuser-augmented wind turbine may include an annular diffuser extended between a first annular leading edge and a first annular trailing edge. An exemplary diffuser-augmented wind turbine may further include a rotor that may be disposed within an exemplary annular diffuser. An exemplary rotor may include a hub and at least one rotor blade that may be coupled to the exemplary hub. An exemplary rotor may be coaxial with an exemplary annular diffuser about a main axis. An exemplary rotor may be rotatable about an exemplary main axis on a rotor plane perpendicular to the exemplary main axis. An exemplary first annular leading edge may be configured to allow a first air stream to be provided to an exemplary rotor plane.

[0006] An exemplary diffuser-augmented wind turbine may further include a flared diffuser assembly. An exemplary flared diffuser assembly may include a second annular leading edge and a second annular trailing edge. An exemplary flared diffuser may be coaxially coupled to an exemplary annular diffuser about an exemplary main axis. An exemplary second leading edge may be in fluid communication with an exemplary first trailing edge. An exemplary second leading edge may be configured to allow a first air stream received from an exemplary first trailing edge to enter an exemplary flared diffuser assembly.

[0007] An exemplary flared diffuser assembly may further include a fixed flared diffuser. An exemplary fixed flared diffuser may include a first plurality of flared petals that may extend from an exemplary second annular leading edge toward an exemplary second annular trailing edge. Each exemplary flared petal of the first plurality of flared petals may include a flared curved conical segment with a first edge attached to an exemplary second annular leading edge and a second edge forming a portion of an exemplary second trailing edge. The first plurality of flared petals may be equally spaced apart around an exemplary second annular leading edge.

[0008] An exemplary flared diffuser assembly may further include a rotatable flared diffuser. An exemplary rotatable flared diffuser may include an annular leading edge that may be

disposed within and encompassed by an exemplary second annular leading edge. An exemplary rotatable diffuser may include a second plurality of flared petals extending from an exemplary annular leading edge toward an exemplary second annular trailing edge. Each exemplary flared petal of the second plurality of flared petals may include a flared curved conical segment with a first edge attached to an exemplary second annular leading edge and a second edge forming a portion of an exemplary second trailing edge. An exemplary rotatable flared diffuser may be coaxial with an exemplary fixed flared diffuser about an exemplary main axis. An exemplary rotatable flared diffuser may be rotatable about an exemplary main axis. An exemplary diffuser-augmented wind turbine may further include a nacelle, where an exemplary hub may be rotatably coupled with an exemplary nacelle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The novel features which are believed to be characteristic of the present disclosure, as to its structure, organization, use and method of operation, together with further objectives and advantages thereof, will be better understood from the following drawings in which a presently preferred embodiment of the present disclosure will now be illustrated by way of example. It is expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the present disclosure. Embodiments of the present disclosure will now be described by way of example in association with the accompanying drawings in which:

[0011] FIG. 1 illustrates a perspective view of a diffuser-augmented wind turbine, consistent with one or more exemplary embodiments of the present disclosure;

[0012] FIGs. 2A-2C illustrate perspective views of a diffuser-augmented wind turbine with different geometries of a flared diffuser assembly, consistent with one or more exemplary embodiments of the present disclosure;

[0013] FIG. 3A illustrates an exploded view of an annular diffuser and a flared diffuser assembly, consistent with one or more exemplary embodiments of the present disclosure;

[0014] FIG. 3B illustrates an exploded view of a fixed flared diffuser, consistent with one or more exemplary embodiments of the present disclosure;

[0015] FIG. 3B illustrates an exploded view of a rotatable flared diffuser, consistent with one or more exemplary embodiments of the present disclosure;

[0016] FIG. 4A illustrates a side view of a diffuser-augmented wind turbine, consistent with one or more exemplary embodiments of the present disclosure;

[0017] FIG. 4B illustrates profiles of an annular diffuser and a fixed flared diffuser, consistent with one or more exemplary embodiments of the present disclosure;

[0018] FIG. 5 illustrates an exploded view of a diffuser-augmented wind turbine, consistent with one or more exemplary embodiments of the present disclosure;

[0019] FIG. 6 illustrates a diffuser-augmented wind turbine system, consistent with one or more exemplary embodiments of the present disclosure; and

[0020] FIG. 7 illustrates a high-level functional block diagram of a computer system, consistent with exemplary embodiments of the present disclosure.

DETAILED DESCRIPTION

[0021] The novel features which are believed to be characteristic of the present disclosure, as to its structure, organization, use and method of operation, together with further objectives and advantages thereof, will be better understood from the following discussion.

[0022] The present disclosure is directed to exemplary embodiments of an exemplary wind turbine that may be augmented by an exemplary variable geometry diffuser. An exemplary variable geometry diffuser may allow for augmenting an exemplary wind turbine to different extents by controlling the diffuser geometry. As used herein, augmenting or augmentation may refer to enhancement of power output of an exemplary wind turbine. An exemplary variable geometry diffuser may allow for increasing augmentation for lower air velocities and may allow for decreasing augmentation for higher air velocities. An exemplary variable geometry diffuser may include an exemplary annular diffuser and a flared diffuser assembly that may be coupled downstream of the exemplary annular diffuser. An exemplary annular diffuser of an exemplary variable geometry diffuser may be mounted around rotor blades of an exemplary wind turbine, such that exemplary rotor blades of an exemplary wind turbine may be encompassed by an exemplary annular diffuser. An exemplary flared diffuser assembly may be attached downstream of an outlet of an exemplary annular diffuser such that air passing through exemplary rotor blades within an exemplary annular diffuser may then enter an exemplary flared diffuser assembly. An exemplary flared diffuser assembly may be a curved diffuser that may flare outward from an axis of symmetry of the curved diffuser towards an outlet of an exemplary flared diffuser assembly. Consequently, flared diffuser assembly may

define a diverging flow path with a curved inner surface with a small dimeter at an inlet of the diverging flow path and a larger diameter at an outlet of the diverging flow path. Such a diverging shape for an exemplary flared diffuser assembly may allow for achieving higher lift coefficients that may lead to an increase in mass flow of air and as a result may enhance the flow of air within an exemplary variable geometry diffuser. Since an exemplary variable geometry diffuser may be in fluid communication with exemplary rotor blades of an exemplary wind turbine, the lift achieved when utilizing such a diverging flared diffuser assembly may increase the air mass flow through exemplary rotor blades. Enhancing the flow of air through exemplary rotor blades may allow for more power per unit mass of air flow to be extracted from the air flow or wind passing through exemplary rotor blades of an exemplary wind turbine.

[0023] However, as wind velocities increase, a drag force that may be exerted on an exemplary diffuser of an exemplary wind turbine may increase as well. At a high wind speed, drag loads acting on an exemplary diffuser may be considerable and may be a major drawback in utilizing diffuser augmented wind turbines. An exemplary variable geometry diffuser may allow for addressing the issue of excessive loading that may be incurred by a diffuser-augmented wind turbine by changing the amount of drag force exerted on a diffuser-augmented wind turbine via changing geometry of an exemplary variable geometry diffuser.

[0024] An exemplary flared diffuser assembly of an exemplary variable geometry diffuser may be divided into two separate sections that together form the complete geometry of an exemplary flared diffuser assembly. A complete geometry of an exemplary flared diffuser assembly may refer to a complete diverging path, where an inner wall of the complete diverging path may flare outward towards an outlet of an exemplary flared diffuser assembly and the inner wall of the complete diverging path may completely enclose the passage between an inlet of an exemplary flared diffuser assembly and an outlet of an exemplary flared diffuser assembly. Exemplary sections of an exemplary flared diffuser assembly may include a fixed flared diffuser and a rotatable flared diffuser. An exemplary fixed flared diffuser may include an annular leading edge out of which three equally spaced apart flared petals may extend toward an outlet of an exemplary flared diffuser assembly. Each exemplary extended petal of an exemplary fixed flared diffuser may cover a portion of the fluid passage between an inlet of an exemplary flared diffuser assembly and an outlet of an exemplary flared diffuser assembly. For example, extended petals may be equally spaced apart petals that each may cover one sixth of the fluid passage between an inlet of an exemplary flared diffuser assembly and an outlet of an

exemplary flared diffuser assembly. Accordingly, exemplary petals of an exemplary fixed flared diffuser may cover half of the fluid passage between an inlet of an exemplary flared diffuser assembly and an outlet of an exemplary flared diffuser assembly.

[0025] An exemplary rotatable flared diffuser may also include an annular leading edge out of which three equally spaced apart flared petals may extend toward an outlet of an exemplary flared diffuser assembly. An exemplary rotatable flared diffuser may be mounted coaxially with an exemplary fixed flared diffuser such that at a certain rotational angle of an exemplary rotatable flared diffuser, an exemplary rotatable flared diffuser and an exemplary fixed flared diffuser may form a complete diverging path. Three exemplary extended petals of an exemplary rotatable flared diffuser may cover half of the fluid passage between an inlet of an exemplary flared diffuser assembly and an outlet of an exemplary flared diffuser assembly. Such two-section design for an exemplary flared diffuser assembly may allow for opening the wall of an exemplary flared diffuser assembly between 50% and 100%. For example, at high wind velocities, 50% of an exemplary diffuser wall may be opened by rotating an exemplary rotatable flared diffuser relative to an exemplary fixed flared diffuser. This way, a smaller portion of an outer surface of an exemplary diffuser may be exposed to high wind velocities and as a result the drag force acting on an exemplary diffuser may be decreased.

[0026] Consequently, at low wind velocities where the drag forces acting on an exemplary diffuser are not that considerable, an exemplary rotatable flared diffuser may be rotated to a rotational position where an exemplary rotatable flared diffuser and an exemplary fixed flared diffuser may form a complete diverging path. However, at higher wind velocities where drag forces acting on an exemplary diffuser may be considerable, an exemplary rotatable flared diffuser may be rotated to a position where exemplary petals of an exemplary rotatable flared diffuser may be positioned immediately below exemplary petals of an exemplary fixed flared diffuser. Here, only one half of an outer surface of an exemplary flared diffuser assembly may be exposed to the wind.

[0027] An exemplary variable geometry diffuser may be equipped with a control mechanism that may utilize a calibration relationship between wind velocities and opening percentages of a wall of an exemplary flared diffuser assembly of an exemplary variable geometry diffuser, to urge an exemplary rotatable flared diffuser to rotate to a predetermined rotational location based at least in part on the wind velocities. An exemplary control mechanism may be coupled in data communication to a wind velocity censor. An exemplary control mechanism may be

configured to receive a wind velocity value from an exemplary wind velocity sensor and based on the received wind velocity and an established calibration relationship to calculate a rotational position for an exemplary rotatable flared diffuser of an exemplary flared diffuser assembly of an exemplary variable geometry diffuser.

[0028] FIG. 1 illustrates a perspective view of a diffuser-augmented wind turbine **10**, consistent with one or more exemplary embodiments of the present disclosure. In an exemplary embodiment, diffuser-augmented wind turbine **10** may include a rotor **12**, which may include rotor blades **12a-c** that may be joined at a central hub **120**. In an exemplary embodiment, rotor **12** may be rotatable about a main axis **122** of diffuser-augmented wind turbine **10**. Central hub **120** may be coupled with a nacelle **124** via a shaft (not illustrated). In an exemplary embodiment, nacelle **124** may be a housing that may house power generating components of diffuser-augmented wind turbine **10**, such as generators, gearboxes, and drive trains that are not illustrated for purpose of simplicity.

[0029] In an exemplary embodiment, diffuser-augmented wind turbine **10** may further include an annular diffuser **14** that may be mounted coaxially with main axis **122** around rotor blades **12a-c**. A narrow gap may be provided between an inner surface of annular diffuser **14** and tips of rotor blades **12a-c**. In an exemplary embodiment, annular diffuser **14** may include a leading edge **140** that may function as an annular inlet end **110** of diffuser-augmented wind turbine **10** and a trailing edge **142**. Annular diffuser **14** may extend along main axis **122** between leading edge **140** and trailing edge **142**. In an exemplary embodiment, both leading edge **140** and trailing edge **142** of annular diffuser **14** may be annular or round. In an exemplary embodiment, annular diffuser **14** may encompass and may be in fluid communication with rotor blades **12a-c**, such that an air stream passing through annular diffuser **14** may also pass through rotor blades **12a-c**.

[0030] In an exemplary embodiment, diffuser-augmented wind turbine **10** may further include a flared diffuser assembly **16** that may be mounted coaxially with main axis **122** of diffuser-augmented wind turbine **10**. In an exemplary embodiment, flared diffuser assembly **16** may include a fixed flared diffuser **160** and a rotatable flared diffuser **162** that may be coaxially coupled with each other. In an exemplary embodiment, rotatable flared diffuser **162** may be rotatable about main axis **122**. In an exemplary embodiment, based on the rotational position of rotatable flared diffuser **162** about main axis **122**, a wall of flared diffuser assembly **16** may be completely closed or partially open. In a completely closed state, flared diffuser assembly

16 may be in a shape of a flared truncated curved cone. In an exemplary embodiment, an annular outlet end **112** of diffuser-augmented wind turbine **10** may be defined by trailing edges of fixed flared diffuser **160** and a rotatable flared diffuser **162**, as will be discussed in the following paragraphs.

[0031] In an exemplary embodiment, central hub **120**, nacelle **124**, annular diffuser **14**, fixed flared diffuser **160**, and rotatable flared diffuser **162** may be mounted coaxially about main axis **122**. In an exemplary embodiment, diffuser-augmented wind turbine **10** may be supported by a tower structure **18**.

[0032] FIG. 3A illustrates an exploded view of annular diffuser **14** and flared diffuser assembly **16**, consistent with one or more exemplary embodiments of the present disclosure. In an exemplary embodiment, fixed flared diffuser **160** may include an annular leading edge **1600** that may be positioned in line with or slightly upstream of trailing edge **142** of annular diffuser **14**. In an exemplary embodiment, annular leading edge **1600** of fixed flared diffuser **160** may be coupled in fluid communication with trailing edge **142** of annular diffuser **14**, such that wind blowing through annular diffuser **14** may exit annular diffuser **14** via trailing edge **142** and may enter fixed flared diffuser **160** via annular leading edge **1600**. In an exemplary embodiment, fixed flared diffuser **160** may further include first flared petals **1602a-c** that may extend between annular leading edge **1600** and annular outlet end **112** of diffuser-augmented wind turbine **10**. In an exemplary embodiment, first flared petals **1602a-c** may flare out toward annular outlet end **112** of diffuser-augmented wind turbine **10**. As used herein, flaring out may refer to being curved outwardly with respect to main axis **122**. In an exemplary embodiment, fixed flared diffuser **160** may include at least one first flared petal that may be structurally similar to first flared petals **1602a-c**. In an exemplary embodiment, fixed flared diffuser **160** may include more than three flared petals that may be structurally similar to first flared petals **1602a-c**.

[0033] FIG. 3B illustrates an exploded view of fixed flared diffuser **160**, consistent with one or more exemplary embodiments of the present disclosure. In an exemplary embodiment, fixed flared diffuser **160** may include an annular ring **1604** and first flared petals **1602a-c** that may either be integrally formed with or attached to annular ring **1604**. In an exemplary embodiment, each flared petal of first flared petals **1602a-c** may include a leading edge attached to or integrally formed with annular ring **1604**, and a trailing edge that may cover a portion of annular outlet end **122** of diffuser-augmented wind turbine **10**. For example, first flared petal

1602a may include leading edge **16022a** that may be attached to or integrally formed with annular ring **1604**. First flared petal **1602a** may extend between leading edge **16022a** and a trailing edge **16020a** confined between a first side edge **16024a** and a second side edge **16026a**. In an exemplary embodiment, leading edge **16022a** and trailing edge **16020a** may include arcs of predetermined angles between first side edge **16024a** and second side edge **16026a**. In an exemplary embodiment, first side edge **16024a** may be a curve that may curve outward with respect to main axis **122** and first flared petal **1602a** may be formed by lathing first side edge **16024a** about main axis **122**.

[0034] In an exemplary embodiment, first flared petal **1602b** may be structurally similar to first flared petal **1602a**. First flared petal **1602b** may include a first side edge **16024b** and a second side edge **16026b**. In an exemplary embodiment, first flared petal **1602c** may be structurally similar to first flared petal **1602a** and first flared petal **1602b**. First flared petal **1602c** may include a first side edge **16024c** and a second side edge **16026c**.

[0035] In an exemplary embodiment, first flared petals **1602a-c** may be equally spaced apart about a periphery of annular leading edge **1600**. In an exemplary embodiment, annular outlet end **122** of diffuser-augmented wind turbine **10** may be a 360° round outlet, a portion of which may be covered by trailing edges **16020a-c** of first flared petals **1602a-c**. For example, trailing edges **16020a-c** of first flared petals **1602a-c** may be 60° arcs that together may cover 180° of a 360° annular outlet end **112** of diffuser-augmented wind turbine **10**. For example, leading edge **16022a** and trailing edge **16020a** may include 60° arcs extended between first side edge **16024a** and second side edge **16026a**.

[0036] In an exemplary embodiment, each flared petal of first flared petals **1602a-c** may flare out towards annular outlet end **112** of diffuser-augmented wind turbine **10**. As used herein, each flared petal of first flared petals **1602a-c** flaring out may refer to each flared petal of first flared petals **1602a-c** being curved outward with respect to main axis **122** as each flared petal of first flared petals **1602a-c** extends from leading edge of that flared petal to the respective trailing edge of that flared petal**.** For example, flared petal **1602a** may flare out with respect to main axis **122** as flared petal **1602a** extends from leading edge **16022a** towards trailing edge **16020a**.

[0037] In an exemplary embodiment, rotatable flared diffuser **162** may include an annular leading edge **1620** that may be positioned in line with or slightly upstream of trailing edge **142** of annular diffuser **14**. In an exemplary embodiment, annular leading edge **1620** of rotatable

flared diffuser **162** may be rotatably coupled with annular leading edge **1600** of fixed flared diffuser **160**. For example, annular leading edge **1620** may fit within annular leading edge **1600** such that leading edge **1600** may encompass annular leading edge **1620**. In an exemplary embodiment, annular leading edge **1620** may rotate about main axis **122** and may be in fluid communication with trailing edge **142** of annular diffuser **14**, such that wind blowing through annular diffuser **14** may exit annular diffuser **14** via trailing edge **142** and may enter rotatable flared diffuser **162** via annular leading edge **1620**. In an exemplary embodiment, rotatable flared diffuser **162** may further include second flared petals **1622a-c** that may extend between annular leading edge **1620** and annular outlet end **112** of diffuser-augmented wind turbine **10**. In an exemplary embodiment, second flared petals **1622a-c** may flare out toward annular outlet end **112** of diffuser-augmented wind turbine **10**. In an exemplary embodiment, rotatable flared diffuser **162** may include at least one second flared petal that may be structurally similar to second flared petals **1622a-c**. In an exemplary embodiment, rotatable flared diffuser **162** may include more than three flared petals that may be structurally similar to second flared petals **1622a-c**.

[0038] FIG. 3C illustrates an exploded view of rotatable flared diffuser **162**, consistent with one or more exemplary embodiments of the present disclosure. In an exemplary embodiment, rotatable flared diffuser **162** may be structurally similar to fixed flared diffuser **160**. In an exemplary embodiment, rotatable flared diffuser **162** may include an annular ring **1624** and second flared petals **1622a-c** that may either be integrally formed with or attached to annular ring **1624**. In an exemplary embodiment, each flared petal of second flared petals **1622a-c** may include a leading edge attached to or integrally formed with annular ring **1624**, and a trailing edge that may cover a portion of annular outlet end **122** of diffuser-augmented wind turbine **10**. For example, second flared petal **1622a** may include leading edge **16222a** that may be attached to or integrally formed with annular ring **1624**. Second flared petal **1622a** may extend between leading edge **16222a** and a trailing edge **16220a** confined between a first side edge **16224a** and a second side edge **16226a**. In an exemplary embodiment, leading edge **16222a** and trailing edge **16220a** may include arcs of predetermined angles between first side edge **16224a** and second side edge **16226a**. In an exemplary embodiment, first side edge **16224a** may be a curve that may curve outward with respect to main axis **122** and second flared petal **1622a** may be formed by lathing first side edge **16224a** about main axis **122**.

[0039] In an exemplary embodiment, second flared petal **1622b** may be structurally similar to second flared petal **1622a**. Second flared petal **1622b** may include a first side edge **16224b** and a second side edge **16226b**. In an exemplary embodiment, second flared petal **1622c** may be structurally similar to second flared petal **1622a** and second flared petal **1622b**. Second flared petal **1622c** may include a first side edge **16224c** and a second side edge **16226c**.

[0040] In an exemplary embodiment, second flared petals **1622a-c** may be equally spaced apart about a periphery of annular leading edge **1620**. In an exemplary embodiment, annular outlet end **122** of diffuser-augmented wind turbine **10** may be a 360° round outlet, a portion of which may be covered by trailing edges **16220a-c** of second flared petals **1622a-c**. For example, trailing edges **16220a-c** of second flared petals **1622a-c** may be 60° arcs that together may cover 180° of a 360° annular outlet end **112** of diffuser-augmented wind turbine **10**. For example, leading edge **16222a** and trailing edge **16220a** may include 60° arcs extended between first side edge **16224a** and second side edge **16226a**.

[0041] In an exemplary embodiment, each flared petal of second flared petals **1622a-c** may flare out towards annular outlet end **112** of diffuser-augmented wind turbine **10**. As used herein, each flared petal of second flared petals **1622a-c** flaring out may refer to each flared petal of second flared petals **1622a-c** being curved outward with respect to main axis **122** as each flared petal of second flared petals **1622a-c** extends from leading edge of that flared petal to the respective trailing edge of that flared petal**.** For example, second flared petal **1622a** may flare out with respect to main axis **122** as second flared petal **1622a** extends from leading edge **16222a** towards trailing edge **16220a**.

[0042]

[0043] **FIG. 4A** illustrates a side view of diffuser-augmented wind turbine **10**, consistent with one or more exemplary embodiments of the present disclosure. **FIG. 4B** illustrates profiles of annular diffuser **14** and fixed flared diffuser **160**, consistent with one or more exemplary embodiments of the present disclosure. In an exemplary embodiment, leading edge **140** and trailing edge **142** of annular diffuser **14** may be annular or in other words round. Annular diffuser **14** may extend between leading edge **140** and trailing edge **142** in three sections, namely, a converging section **144**, a straight section **146**, and a diverging section **148**. In an exemplary embodiment, converging section **144** may be a section of reducing diameter that extends from leading edge **140** towards a plane of rotor blades **12a-c**. As used herein, the plane of rotor blades **12a-c** may refer to a plane define by the tips of rotor blades **12a-c**, where the

plane may be perpendicular to main axis **122**. Wind blowing through diffuser-augmented wind turbine **10** may pass the plane of rotor blades **12a-c**. In an exemplary embodiment, straight portion **146** may be a portion of annular diffuser **14** that encompasses rotor blades **12a-c**. A small gap **1410** may be defined between an inner surface of straight portion **146** and tips of rotor blades **12a-c**. In an exemplary embodiment, diverging portion **148** may follow straight portion **146** and may function as an ejector. Diverging portion **148** extends towards trailing edge **142** of annular diffuser **14**. In other words, an air stream may enter annular diffuser through annular leading edge **140** and then may pass through converging section **144**. After that, the air stream may pass through the plane of rotor blades **12a-c** through straight portion **146** and then the air flow may exit through diverging section **148** towards trailing edge **142**. In an exemplary embodiment, energy of an air stream that may enter leading edge **140** of annular diffuser **14** may be extracted by rotor blades **12a-c**.

[0044] In an exemplary embodiment, leading edge **1600** of fixed flared diffuser **160** may be in line with or partially upstream of trailing edge **142** of annular diffuser **14**. Referring to **FIGs. 4A** and **4B**, in an exemplary embodiment, leading edge **1600** of fixed flared diffuser **160** may be partially upstream of trailing edge **142** of annular diffuser **14**. As used herein, upstream and downstream may be defined based on the wind flow direction. For example, in a wind flow with a direction shown by arrow **40**, upstream is defined at leading edge **140** and downstream is defined as any point after the upstream in the direction shown by arrow **40**. For example, leading edge **1600** of fixed flared diffuser **160** being partially upstream of trailing edge **142** of annular diffuser **14** may refer to trailing edge **142** of annular diffuser **14** being extended partially beyond leading edge **1600** of fixed flared diffuser **160** in the direction shown by arrow **40**.

[0045] In an exemplary embodiment, fixed flared diffuser **160** may be coupled with annular diffuser **14** such that an annular gap **42** may exist between leading edge **1600** of fixed flared diffuser **160** and trailing edge **142** of annular diffuser **14**. In an exemplary embodiment, annular gap **42** may allow for an air stream to bypass annular diffuser **14** and directly enter flared diffuser assembly **16**. In an exemplary embodiment, an air stream exiting annular diffuser **14** may be mixed with an air stream entering through annular gap **42** and may enter flared diffuser assembly **16**. In an exemplary embodiment, leading edge **1600** of fixed flared diffuser **160** may be fixedly attached to trailing edge **142** of annular diffuser **14**. In an exemplary embodiment, leading edge **140** may be upstream of rotor blades **12a-c**.

[0046] **FIG. 5** illustrates an exploded view of diffuser-augmented wind turbine **10**, consistent with one or more exemplary embodiments of the present disclosure. In an exemplary embodiment, annular diffuser **14** may be supported on nacelle **124** by utilizing struts **50**. In an exemplary embodiment, struts **50** may be connected to nacelle **124** via first connecting ring **52** that may be disposed within a first groove **54** on nacelle **124**. In an exemplary embodiment, rotor blades **12a-c** may be mounted on nacelle **124** via central hub **120**, such that rotor blades **12a-c** may be rotatable within and coaxial with annular diffuser **14** about main axis **122**.

[0047] In an exemplary embodiment, fixed flared diffuser **160** may be fixedly mounted on trailing edge **142** of annular diffuser **14**. For example, fixed flared diffuser **160** may be connected to trailing edge **142** utilizing coupling member **55** that may include struts **550** and coupling ring **552**. In an exemplary embodiment, coupling ring **552** may be disposed within coupling groove **57** on nacelle **124** downstream of rotor blades **12a-c**. that may allow for mounting fixed flared diffuser **160** on trailing edge **142** of annular diffuser **14**, such that small gap **1410** may be formed between trailing edge **142** and leading edge **1600** of fixed flared diffuser **160**. In an exemplary embodiment, fixed flared diffuser **160** may further be coupled with nacelle **124** via an extra ring **56** that may be coupled with coupling member **55** by a number of coupling struts **58**.

[0048] In an exemplary embodiment, rotatable flared diffuser **162** may be coaxially disposed within fixed flared diffuser **160**, such that rotatable flared diffuser **124** may be rotated relative to nacelle **124** about main axis **122**. In exemplary embodiments, such rotation of rotatable flared diffuser within fixed flared diffuser may allow for changing a shape of flared diffuser assembly **16**.

[0049] **FIGs. 2A-2C** illustrate perspective views of diffuser-augmented wind turbine **10** with flared diffuser assembly **16** with rotatable flared diffuser **162** at different rotational positions, consistent with one or more exemplary embodiments of the present disclosure. In an exemplary embodiment, a rotational position of rotatable flared diffuser **162** may be defined with respect to main axis **122**. In an exemplary embodiment, rotatable flared diffuser **162** may be rotated to a first rotational position where second flared petals **1622a-c** of rotatable flared diffuser **162** may be positioned in empty spaces between each pair of first flared petals **1602a-c**, such that trailing edges **16220a-c** and trailing edges **16020a-c** may form 360° annular outlet end **112** of diffuser-augmented wind turbine **10** as illustrated in **FIG. 1**. In an exemplary embodiment, in the first rotational position, edges of each flared petal of second flared petals **1622a-c** may be

positioned in line with respective edges of adjacent flared petals of first flared petals **1602a-c**. In other words, a first side edge of each flared petal of second flared petals **1622a-c** may be positioned in line with an edge of a respective adjacent flared petal of first flared petals **1602a-c** and a second side edge of each flared petal of second flared petals **1622a-c** may be positioned in line with an edge of a respective adjacent flared petal of first flared petals **1602a-c**. For example, **FIG. 1** illustrates the first rotational position of rotatable flared diffuser **162**, in which, second flared petal **1622a** is positioned between first flared petal **1602a** and first flared petal **1602b**. As used herein, second flared petal **1622a** being positioned between first flared petal **1602a** and first flared petal **1602b** may refer to a position where first side edge **16224a** of second flared petal **1622a** is in line with second side edge **16026b** of first flared petal **1602b** and second side edge **16226a** of second flared petal **1622a** is in line with first side edge **16024a** of first flared petal **1602a**. In the first rotational position of rotatable flared diffuser **162** as described above, flared diffuser assembly **16** may have a truncated curved cone shape.

[0050] In an exemplary embodiment, rotatable flared diffuser **162** may be rotated to a rotational position, where a portion of empty spaces between each pair of first flared petals **1602a-c** may be filled with second flared petals **1622a-c** of rotatable flared diffuser **162**, for example, as illustrated in **FIGs. 2A** and **2B**. In an exemplary embodiment, rotatable flared diffuser **162** may be rotated to a second rotational position, where none of empty spaces between each pair of first flared petals **1602a-c** may be filled with second flared petals **1622a-c** of rotatable flared diffuser **162**, for example, as illustrated in **FIG. 2C**.

[0051] In an exemplary embodiment, in the second rotational position of rotatable flared diffuser **162**, edges of each flared petal of second flared petals **1622a-c** may be positioned in line with respective edges of a corresponding flared petal of first flared petals **1602a-c**. For example, first side edge **16224a** of second flared petal **1622a** may be positioned in line with first side edge **16024a** of first flared petal **1602a**. First side edge **16224b** of second flared petal **1622b** may be positioned in line with first side edge **16024b** of first flared petal **1602b**. First side edge **16224c** of second flared petal **1622c** may be positioned in line with first side edge **16024c** of first flared petal **1602c**.

[0052] In the second rotational position as described above, second flared petals **1622a-c** of rotatable flared diffuser **162** may be positioned immediately below first flared petals **1602a-c** of fixed flared diffuser **160**. In an exemplary embodiment, such rotation of rotatable flared diffuser **162** with respect to fixed flared diffuser **160** between the first rotational position and

the second rotational position may allow for changing the shape of flared diffuser assembly **16** from a complete flared diffuser with an annular or round outlet to a flared diffuser with an outlet that only 180° of its round outlet is covered by trailing edges **16020a-c** as illustrated in **FIG. 2C**.

[0053] FIG. 6 illustrates a diffuser-augmented wind turbine system **60**, consistent with one or more exemplary embodiments of the present disclosure. In an exemplary embodiment, diffuser-augmented wind turbine **10** may be an implementation of system **60**. In an exemplary embodiment, system **60** may include a wind turbine **62** that may include a rotor **620** that may be similar to rotor **12** and a nacelle **622** that may be similar to nacelle **124**. In an exemplary embodiment, rotor **12** may be coupled with nacelle **124** via a shaft and may transfer the mechanical power extracted from an air stream to nacelle **124**. In an exemplary embodiment, nacelle **124** may include generating parts of wind turbine **62**, for example, an electric generator that may receive the mechanical power and may convert the mechanical power into electricity.

[0054] In an exemplary embodiment, system **60** may further include a variable geometry diffuser **64** that may be coupled with wind turbine **62** to augment the energy output of wind turbine **62** by enhancing the mass flow rate of air passing through wind turbine **62**. Variable geometry diffuser **64** may generate a lift within the air flow through wind turbine **62**, which may lead to an increase in air mass flow passing through wind turbine **62.** Therefore, more power per unit mass of air flow may be extracted from the air flow or wind passing through exemplary rotor blades of wind turbine **62.** In an exemplary embodiment, variable geometry diffuser **64** may include an annular diffuser **640** that may be similar to annular diffuser **14**, a fixed flared diffuser **642** that may be similar to fixed flared diffuser **160**, and a rotatable flared diffuser **644** that may be similar to rotatable flared diffuser **162**. In an exemplary embodiment, annular diffuser **640** may be coupled with wind turbine **62** such that annular diffuser **640** may be mounted coaxial with rotor **620** and nacelle **622** about a main axis. Annular diffuser **640** may encompass rotor **620** similar to annular diffuser **14** encompassing rotor **12** in diffuser-augmented wind turbine **12**. In an exemplary embodiment, annular diffuser **640** may be in fluid communication with rotor **620**, i.e., an air stream passing through annular diffuser **640** may pass through rotor **620** and the energy of the air stream may be extracted by rotor **620**. In an exemplary embodiment, the extracted energy by rotor **620** may be converted to electricity by a generator housed within nacelle **622**.

[0055] In an exemplary embodiment, fixed flared diffuser **642** may be mounted coaxial with and downstream of annular diffuser **640** similar to fixed flared diffuser **160** mounted coaxial with and downstream of annular diffuser **14**. In an exemplary embodiment, fixed flared diffuser **642** may be in fluid communication with annular diffuser **640**, i.e., an air stream passing through annular diffuser **640** may pass through fixed flared diffuser **642**. In an exemplary embodiment, fixed flared diffuser **642** may be structurally similar to fixed flared diffuser **160**, meaning that, fixed flared diffuser **642** may include an annular leading edge similar to annular leading edge **1600** that may be positioned in line with or slightly upstream of a trailing edge of annular diffuser **642** that may be similar to trailing edge **142** of annular diffuser **14**. In an exemplary embodiment, the annular leading edge of fixed flared diffuser **642** may be coupled in fluid communication with the trailing edge of annular diffuser **640** similar to annular leading edge **1600** of fixed flared diffuser **160** coupled in fluid communication with trailing edge **142** of annular diffuser **14**. In an exemplary embodiment, fixed flared diffuser **642** may further include first flared petals similar to first flared petals **1602a-c** that may extend from the annular leading edge of fixed flared diffuser **642** toward an annular outlet end of wind turbine **62** that may be similar to annular outlet end **112** of diffuser-augmented wind turbine **10**. In an exemplary embodiment, the first flared petals may flare out toward the annular outlet end of wind turbine **62**.

[0056] In an exemplary embodiment, rotatable flared diffuser **644** may be mounted coaxial with and within fixed flared diffuser **642** similar to rotatable flared diffuser **162** mounted coaxial with and within fixed flared diffuser **160**. In an exemplary embodiment, rotatable flared diffuser **644** may be rotatable with respect to fixed flared diffuser **642** similar to rotatable flared diffuser **162** rotatable relative to fixed flared diffuser **160** about main axis **122**. In an exemplary embodiment, rotatable flared diffuser **644** may be in fluid communication with annular diffuser **640**, i.e., an air stream passing through annular diffuser **640** may pass through rotatable flared diffuser **644**. In an exemplary embodiment, rotatable flared diffuser **644** may be structurally similar to rotatable flared diffuser **162**, meaning that, rotatable flared diffuser **644** may include an annular leading edge similar to annular leading edge **1620** that may be positioned coaxially within annular leading edge **1600** of fixed flared diffuser **160**. In an exemplary embodiment, the annular leading edge of rotatable flared diffuser **644** may be coupled in fluid communication with the trailing edge of annular diffuser **640** similar to annular leading edge **1620** of rotatable flared diffuser **162** coupled in fluid communication with trailing edge **142** of

annular diffuser **14**. In an exemplary embodiment, rotatable flared diffuser **644** may further include second flared petals similar to second flared petals **1622a-c** that may extend from the annular leading edge of rotatable flared diffuser **644** toward an annular outlet end of wind turbine **62** that may be similar to annular outlet end **112** of diffuser-augmented wind turbine **10**. In an exemplary embodiment, the second flared petals may flare out toward the annular outlet end of wind turbine **62**.

[0057] In an exemplary embodiment, rotatable flared diffuser **644** may be rotated relative to fixed flared diffuser **642** between a first rotational position and a second rotational position. In the first rotational position, the second flared petals of rotatable flared diffuser **644** may fill in the empty spaces between the first flared petals of fixed flared diffuser **642** similar to second flared petals **1622a-c** filling in the empty spaces between first flared petals **1602a-c** as illustrated in **FIG. 1**. In the second rotational position, the second flared petals of rotatable flared diffuser **644** may be positioned immediately below the second flared petals of fixed flare diffuser **642** similar to second flared petals **1622a-c** positioned immediately below first flared petals **1602a-c** as illustrated in **FIG. 2C**. In an exemplary embodiment, in the first rotational position, fixed flared diffuser **642** and rotatable flared diffuser **644** may form a truncated curved cone and in the second rotational position, rotatable flared diffuser **644** may be positioned below fixed flared diffuser **642** and together fixed flared diffuser **642** and rotatable flared diffuser **644** may form a truncated curved cone with open segments in the wall of the truncated curved cone**.** In an exemplary embodiment, outer surface area of variable geometry diffuser **64** that may be exposed to wind in the first rotational position is more than the surface area of variable geometry diffuser **64** exposed to wind in the second rotational position. Consequently, drag forces acting on variable geometry diffuser **64** in the second rotational position are less than the drag forces acting on variable geometry diffuser **64** in the first position for a given wind velocity. In exemplary embodiments, such rotation of rotatable flared diffuser **644** from the first rotational position to the second rotational position may allow for rotating rotatable flared diffuser **644** to the second position in high wind velocities to reduce the drag forces acting on variable geometry diffuser **64** and rotate rotatable flared diffuser **644** to the first position at lower wind velocities to compensate for the low mass flow rate of air passing through wind turbine **62**.

[0058] In an exemplary embodiment, system **60** may further include a rotary actuator **66** that may be coupled with rotatable flared diffuser **644.** Rotary actuator **66** may be configured to

actuate a rotational movement of rotatable flared diffuser **644** between the first rotational position and the second rotational position. In an exemplary embodiment, rotary actuator **66** may be an electric motor coupled with rotatable flared diffuser **644**.

[0059] In an exemplary embodiment, system **60** may further include a sensor system **610** that may include a position sensor **6102** and a wind velocity sensor **6104**. In an exemplary embodiment, position sensor **6102** may be coupled to rotary actuator **66.** Position sensor **6102** may be configured to sense and transmit a rotational position of rotary actuator **66** at every instant. In an exemplary embodiment, wind velocity sensor **6104** may be configured to measure and transmit wind velocity at every instant.

[0060] In an exemplary embodiment, system **60** may further include a controller **68** that may be coupled with rotary actuator **66** and sensor system **610**. In an exemplary embodiment, controller **68** may be configured to receive a current rotational position of rotatable flared diffuser **644** from position sensor **6102** and a wind velocity data from wind velocity sensor **6104**. In an exemplary embodiment, controller **68** may further be configured to calculate a new rotational position for rotatable flared diffuser **644** based on an established calibration relationship between wind velocity and rotational position of rotatable flared diffuser **644** and the received current rotational position and the wind velocity data. In an exemplary embodiment, controller **68** may further be configured to urge rotary actuator **66** to rotate rotatable flared diffuser **644** from a current position toa new position. In an exemplary embodiment, a calibration relationship between wind velocities and rotational position of rotatable flared diffuser **644** may be established by calculating drag forces acting on variable geometry diffuser **64** in a wind tunnel experimental setup and minimizing the drag forces acting on variable geometry diffuser **64** at different wind velocities by changing the rotational position of rotatable flared diffuser **644**.

[0061] FIG. 7 illustrates a high-level functional block diagram of a computer system **700**, in which an embodiment of the present invention, or portions thereof, may be implemented as computer-readable code, consistent with exemplary embodiments of the present disclosure. For example, controller **68** may be implemented as computer system **700** using hardware, software, firmware, tangible computer-readable media having instructions stored thereon, or a combination thereof and may be implemented in one or more computer systems or other processing systems.

[0062] If controller 68 is implemented as a programmable logic, such logic may execute on a commercially available processing platform or a special purpose device. One ordinary skill in the art may appreciate that an embodiment of the disclosed subject matter can be practiced with various computer system configurations, including multi-core multiprocessor systems, minicomputers, mainframe computers, computers linked or clustered with distributed functions, as well as pervasive or miniature computers that may be embedded into virtually any device.

[0063] For instance, a computing device having at least one processor device and a memory may be used to implement the above-described embodiments. A processor device may be a single processor, a plurality of processors, or combinations thereof. Processor devices may have one or more processor "cores."

[0064] An embodiment of the invention is described in terms of this example computer system **700**. After reading this description, it will become apparent to a person skilled in the relevant art how to implement the invention using other computer systems and/or computer architectures. Although operations may be described as a sequential process, some of the operations may be performed in parallel, concurrently, and/or in a distributed environment, and with program code stored locally or remotely for access by single or multi-processor machines. Also, in some embodiments, the order of operations may be rearranged without departing from the spirit of the disclosed subject matter.

[0065] Processor device **704** may be a special purpose or a general-purpose processor device. As will be appreciated by persons skilled in the relevant art, processor device **704** may also be a single processor in a multi-core/multiprocessor system, such system operating alone, or in a cluster of computing devices operating in a cluster or server farm. Processor device **704** may be connected to a communication infrastructure **706**, for example, a bus, message queue, network, or multi-core message-passing scheme.

[0066] In an exemplary embodiment, computer system **700** may include a display interface **702**, for example, a video connector, to transfer data to a display unit **730**, for example, a monitor. Computer system **700** may also include a main memory **708**, for example, random access memory (RAM), and may also include a secondary memory **710**. Secondary memory **710** may include, for example, a hard disk drive **712**, and a removable storage drive **714**. Removable storage drive **714** may include a floppy disk drive, a magnetic tape drive, an optical disk drive, a flash memory, or the like. Removable storage drive **714** may read from and/or

write to a removable storage unit **718** in a well-known manner. Removable storage unit **718** may include a floppy disk, a magnetic tape, an optical disk, etc., which may be read by and written to by removable storage drive **714**. As will be appreciated by persons skilled in the relevant art, removable storage unit **718** may include a computer-usable storage medium having stored therein computer software and/or data.

[0067] In alternative implementations, secondary memory **710** may include other similar means for allowing computer programs or other instructions to be loaded into computer system **700**. Such means may include, for example, a removable storage unit **722** and an interface **720**. Examples of such means may include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM, or PROM) and associated socket, and other removable storage units **722** and interfaces **720** which allow software and data to be transferred from removable storage unit **722** to computer system **700**.

[0068] Computer system **700** may also include a communications interface **724**. Communications interface **724** allows software and data to be transferred between computer system **700** and external devices. Communications interface **724** may include a modem, a network interface (such as an Ethernet card), a communications port, a PCMCIA slot, and card, or the like. Software and data transferred via communications interface **724** may be in the form of signals, which may be electronic, electromagnetic, optical, or other signals capable of being received by communications interface **724**. These signals may be provided to communications interface **724** via a communications path **726**. Communications path **726** carries signals and may be implemented using wire or cable, fiber optics, a phone line, a cellular phone link, an RF link or other communications channels.

[0069] In this document, the terms "computer program medium" and "computer usable medium" are used to generally refer to media such as removable storage unit **718**, removable storage unit **722**, and a hard disk installed in hard disk drive **712**. Computer program medium and computer-usable medium may also refer to memories, such as main memory **708** and secondary memory **710**, which may be memory semiconductors (e.g. DRAMs, etc.).

[0070] Computer programs (also called computer control logic) are stored in main memory **708** and/or secondary memory **710**. Computer programs may also be received via communications interface **724**. Such computer programs, when executed, enable computer system **700** to implement different embodiments of the present disclosure as discussed herein. In particular, the computer programs, when executed, enable processor device **704** to

implement the processes of the present disclosure, such as the operations of receiving data from sensor system **610**, where the received data may include the wind velocity and the rotational position of rotatable flared diffuser **644**, receiving a calibration relationship that relates the wind velocity with rotational position of rotatable flared diffuser **644** about the main axis, determining a second rotational position for rotatable flared diffuser **644** about the main axis based on the received data from sensor system **610** and the received calibration relationship, and urging rotary actuator **66** to drive a rotational movement of rotatable flared diffuser **644** form the first rotational position to the second rotational position. Accordingly, such computer programs represent controllers of computer system **700**. Where an exemplary embodiment of such operations as discussed above is implemented using software, the software may be stored in a computer program product and loaded into computer system **700** using removable storage drive **714**, interface **720**, and hard disk drive **712**, or communications interface **724**.

[0071] Embodiments of the present disclosure also may be directed to computer program products including software stored on any computer useable medium. Such software, when executed in one or more data processing devices, causes a data processing device to operate as described herein. An embodiment of the present disclosure may employ any computer useable or readable medium. Examples of computer useable mediums include, but are not limited to, primary storage devices (e.g., any type of random access memory), secondary storage devices (e.g., hard drives, floppy disks, CD ROMS, ZIP disks, tapes, magnetic storage devices, and optical storage devices, MEMS, nanotechnological storage device, etc.).

[0072] While the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications may be made therein and that the subject matter disclosed herein may be implemented in various forms and examples, and that the teachings may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to claim any and all applications, modifications and variations that fall within the true scope of the present teachings.

[0073] Unless otherwise stated, all measurements, values, ratings, positions, magnitudes, sizes, and other specifications that are set forth in this specification, including in the claims that follow, are approximate, not exact. They are intended to have a reasonable range that is consistent with the functions to which they relate and with what is customary in the art to which they pertain.

[0074] The scope of protection is limited solely by the claims that now follow. That scope is intended and should be interpreted to be as broad as is consistent with the ordinary meaning of the language that is used in the claims when interpreted in light of this specification and the prosecution history that follows and to encompass all structural and functional equivalents. Notwithstanding, none of the claims are intended to embrace subject matter that fails to satisfy the requirement of Sections 101, 102, or 103 of the Patent Act, nor should they be interpreted in such a way. Any unintended embracement of such subject matter is hereby disclaimed.

[0075] Except as stated immediately above, nothing that has been stated or illustrated is intended or should be interpreted to cause a dedication of any component, step, feature, object, benefit, advantage, or equivalent to the public, regardless of whether it is or is not recited in the claims.

[0076] It will be understood that the terms and expressions used herein have the ordinary meaning as is accorded to such terms and expressions with respect to their corresponding respective areas of inquiry and study except where specific meanings have otherwise been set forth herein. Relational terms such as first and second and the like may be used solely to distinguish one entity or action from another without necessarily requiring or implying any actual such relationship or order between such entities or actions. The terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element proceeded by "a" or "an" does not, without further constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises the element.

[0077] The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various implementations. This is for purposes of streamlining the disclosure and is not to be interpreted as reflecting an intention that the claimed implementations require more features than are expressly recited in each claim. Rather, as the following claims reflect, the inventive subject matter lies in less than all features of a single disclosed implementation. Thus, the following

claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

[0078] While various implementations have been described, the description is intended to be exemplary, rather than limiting and it will be apparent to those of ordinary skill in the art that many more implementations and implementations are possible that are within the scope of the implementations. Although many possible combinations of features are shown in the accompanying figures and discussed in this detailed description, many other combinations of the disclosed features are possible. Any feature of any implementation may be used in combination with or substituted for any other feature or element in any other implementation unless specifically restricted. Therefore, it will be understood that any of the features shown and/or discussed in the present disclosure may be implemented together in any suitable combination. Accordingly, the implementations are not to be restricted except in light of the attached claims and their equivalents. Also, various modifications and changes may be made within the scope of the attached claims.

[0079] The embodiments have been described above with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries can be defined so long as the specified functions and relationships thereof are appropriately performed.

[0080] The foregoing description of the specific embodiments will so fully reveal the general nature of the disclosure that others can, by applying knowledge within the skill of the art, readily modify and/or adapt for various applications such specific embodiments, without undue experimentation, without departing from the general concept of the present disclosure. Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed embodiments, based on the teaching and guidance presented herein. It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by the skilled artisan in light of the teachings and guidance.

[0081] The breadth and scope of the present disclosure should not be limited by any of the above-described exemplary embodiments but should be defined only in accordance with the following claims and their equivalents.

[0082] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not to the exclusion of any other integer or step or group of integers or steps.

[0083] Moreover, the word "substantially" when used with an adjective or adverb is intended to enhance the scope of the particular characteristic; e.g., substantially planar is intended to mean planar, nearly planar and/or exhibiting characteristics associated with a planar element. Further use of relative terms such as “vertical”, “horizontal”, “up”, “down”, and “side-to-side” are used in a relative sense to the normal orientation of the apparatus.

WHAT IS CLAIMED IS:

1. A diffuser-augmented wind turbine, comprising:

an annular diffuser comprising a first annular leading edge and a first annular trailing edge;

a rotor disposed within the annular diffuser, the rotor comprising a hub and at least one rotor blade coupled to the hub, the rotor coaxial with the annular diffuser about a main axis, the rotor rotatable about the main axis on a rotor plane perpendicular to the main axis, the first annular leading edge configured to allow a first air stream to be provided to the rotor plane;

a flared diffuser assembly comprising a second annular leading edge and a second annular trailing edge, the flared diffuser coaxially coupled to the annular diffuser about the main axis, the second leading edge in fluid communication with the first trailing edge, the second leading edge configured to allow the first air stream received from the first trailing edge to enter the flared diffuser assembly, the flared diffuser assembly further comprising:

a fixed flared diffuser comprising a first plurality of flared petals extending from the second annular leading edge toward the second annular trailing edge, each flared petal of the first plurality of flared petals extended between a first leading edge and a first trailing edge, the first leading edge attached to the second annular leading edge, each flared petal of the first plurality of flared petals further comprising two first side edges, the first leading edge and the first trailing edge comprising arcs extended between the two first side edges;

a rotatable flared diffuser comprising an annular leading edge disposed within and encompassed by the second annular leading edge, the rotatable flared diffuser comprising a second plurality of flared petals extending from the annular leading edge toward the second annular trailing edge, each flared petal of the second plurality of flared petals extended between a second leading edge and a second trailing edge, each flared petal of the second plurality of flared petals further comprising two second side edges, the second leading edge and the second trailing edge comprising arcs extended between the two second side edges;

the rotatable flared diffuser coaxial with the fixed flared diffuser about the main axis, the

a nacelle, the hub rotatably coupled with the nacelle.

2. The diffuser-augmented wind turbine of claim 1, wherein the first plurality of flared petals comprises three equally spaced apart flared petals, each flared petal of the first plurality of flared petals comprising a one-sixth segment of a curved cone extending from the second annular leading edge flaring out towards the second annular trailing edge.

3. The diffuser-augmented wind turbine of claim 2, wherein the second plurality of flared petals comprises three equally spaced apart flared petals, each flared petal the second plurality of flared petals comprising a one-sixth segment of a curved cone extending from the annular leading edge flaring out towards the second trailing edge.

4. The diffuser-augmented wind turbine of claim 2, wherein the rotatable flared diffuser is rotatable between a first rotational position and a second rotational position about the main axis, the first rotational position corresponding to a position wherein each flared petal of the second plurality of flared petals is positioned between two corresponding flared petals of the first plurality of flared petals such that each of the two second side edges of each flared petal of the second plurality of flared petals is in line with a respective side edge of the two first side edges of each flared petals of the two corresponding flared petals.

5. The diffuser-augmented wind turbine of claim 4, wherein the second rotational position corresponding to a position wherein each flared petal of the second plurality of flared petals is immediately positioned behind a corresponding flared petal of the first plurality of flared petals, such the two second side edges of each flared petal of the second plurality of flared petals are in line with respective two first side edges of the corresponding flared petal of the first plurality of flared petals.

6. The diffuser-augmented wind turbine of claim 1, further comprising an annular air gap between an outer surface of the first trailing edge and an inner surface of the second leading edge, the annular air gap configured to allow a second air stream to enter the flared diffuser assembly.

7. The diffuser-augmented wind turbine of claim 6, wherein the second leading edge is mounted upstream of the first trailing edge.

8. The diffuser-augmented wind turbine of claim 6, wherein the second leading edge is attached to the first trailing edge.

9. The diffuser-augmented wind turbine of claim 1, wherein the annular diffuser further comprises a converging section that extends from the first leading edge to the rotor plane, a straight section that encompasses the rotor blades, and a diverging section extending between the straight section and the first trailing edge.

10. The diffuser-augmented wind turbine of claim 1, wherein the fixed flared diffuser is attached to the nacelle via a first plurality of radially extended struts and wherein the rotatable flared diffuser is rotatably attached to the nacelle via a second plurality of radially extended struts.

11. The diffuser-augmented wind turbine of claim 1, further comprising a rotational actuator coupled with the rotatable flared diffuser, the rotational actuator configured to drive a rotational movement of the rotatable flared diffuser about the main axis.

12. The diffuser-augmented wind turbine of claim 11, further comprising a sensor system configured to measure the wind velocity entering the diffuser-augmented wind turbine, the sensor system

further configured to determine a first rotational position of the rotatable flared diffuser about the main axis.

13. The diffuser-augmented wind turbine of claim 12, further comprising a control mechanism coupled with the rotational actuator and the sensor, the control mechanism configured to urge the rotational actuator to rotate the rotatable flared diffuser, the control mechanism comprising:

at least one processor; and

at least one memory coupled to the at least one processor, the at least one memory storing executable instructions to urge the at least one processor to:

receive data from the sensor system, the data comprising the wind velocity and the rotational position of the rotatable flared diffuser;

receive a calibration relationship that relates the wind velocity with rotational position of the rotatable flared diffuser about the main axis;

determine a second rotational position for the rotatable flared diffuser about the main axis based on the received data from the sensor system and the received calibration relationship; and

urge the rotational actuator to drive a rotational movement of the rotatable flared diffuser form the first rotational position to the second rotational position.

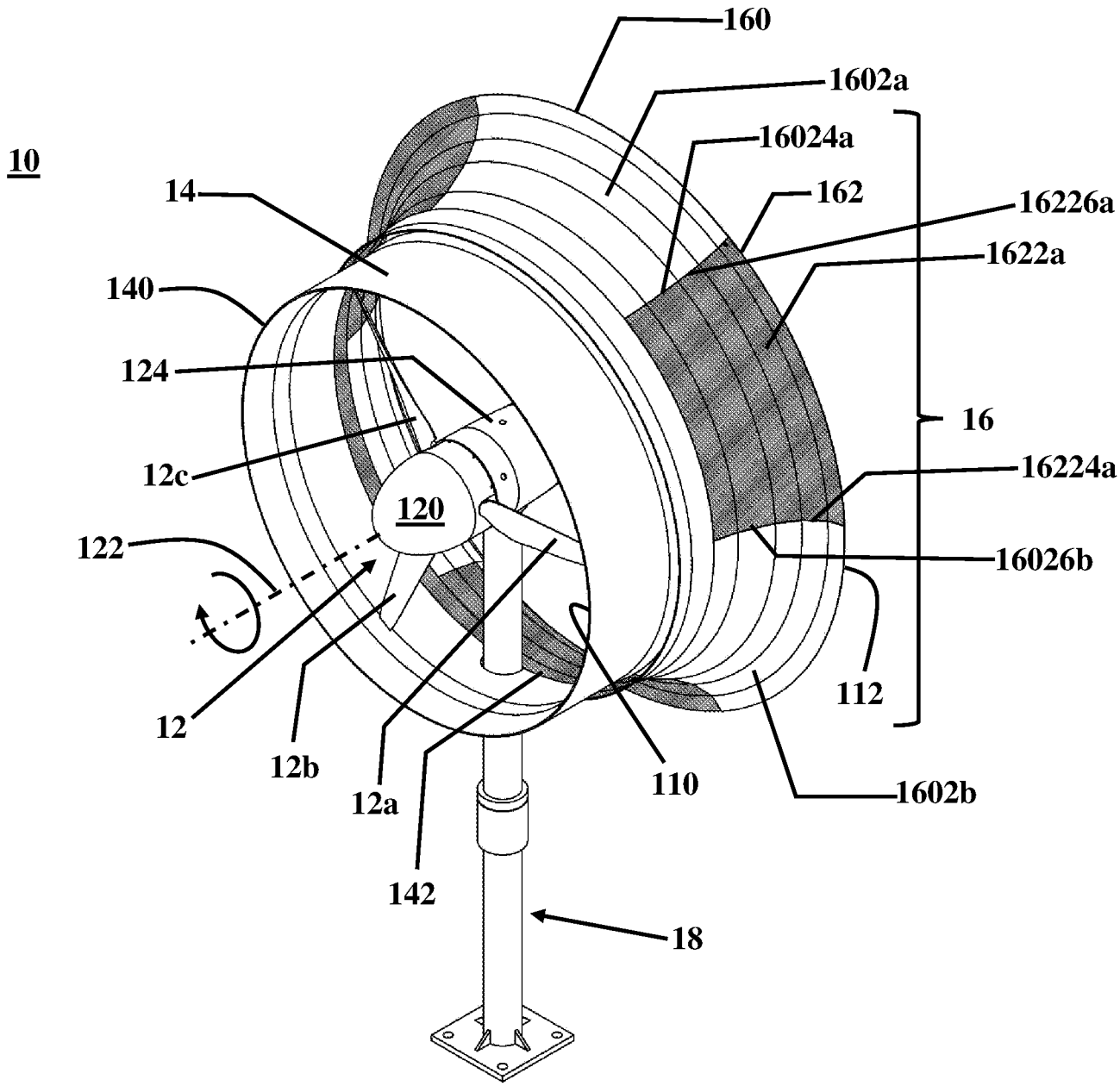

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12b
12a
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16224a
16026b
1602b
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FIG. 1

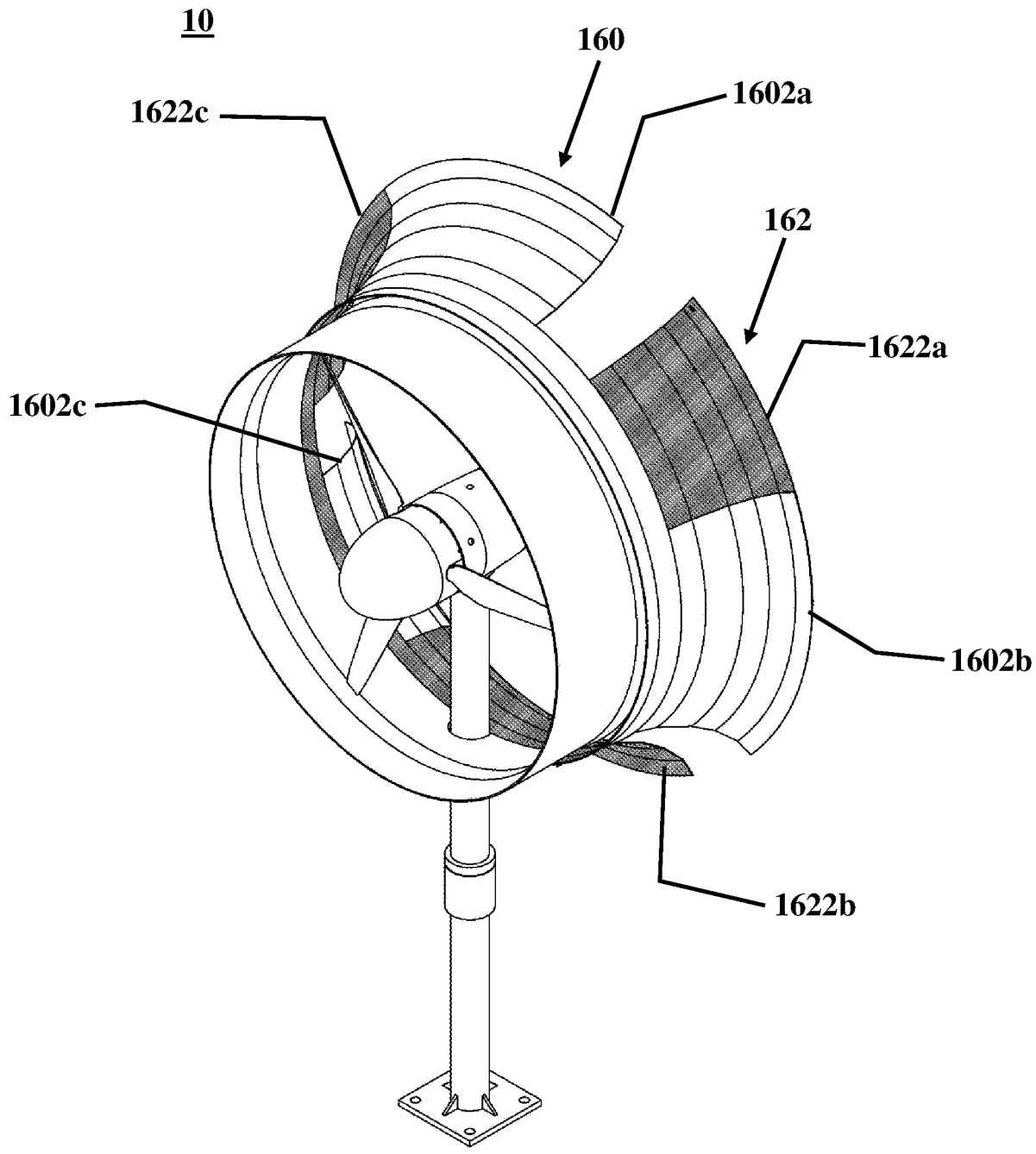


FIG. 2A

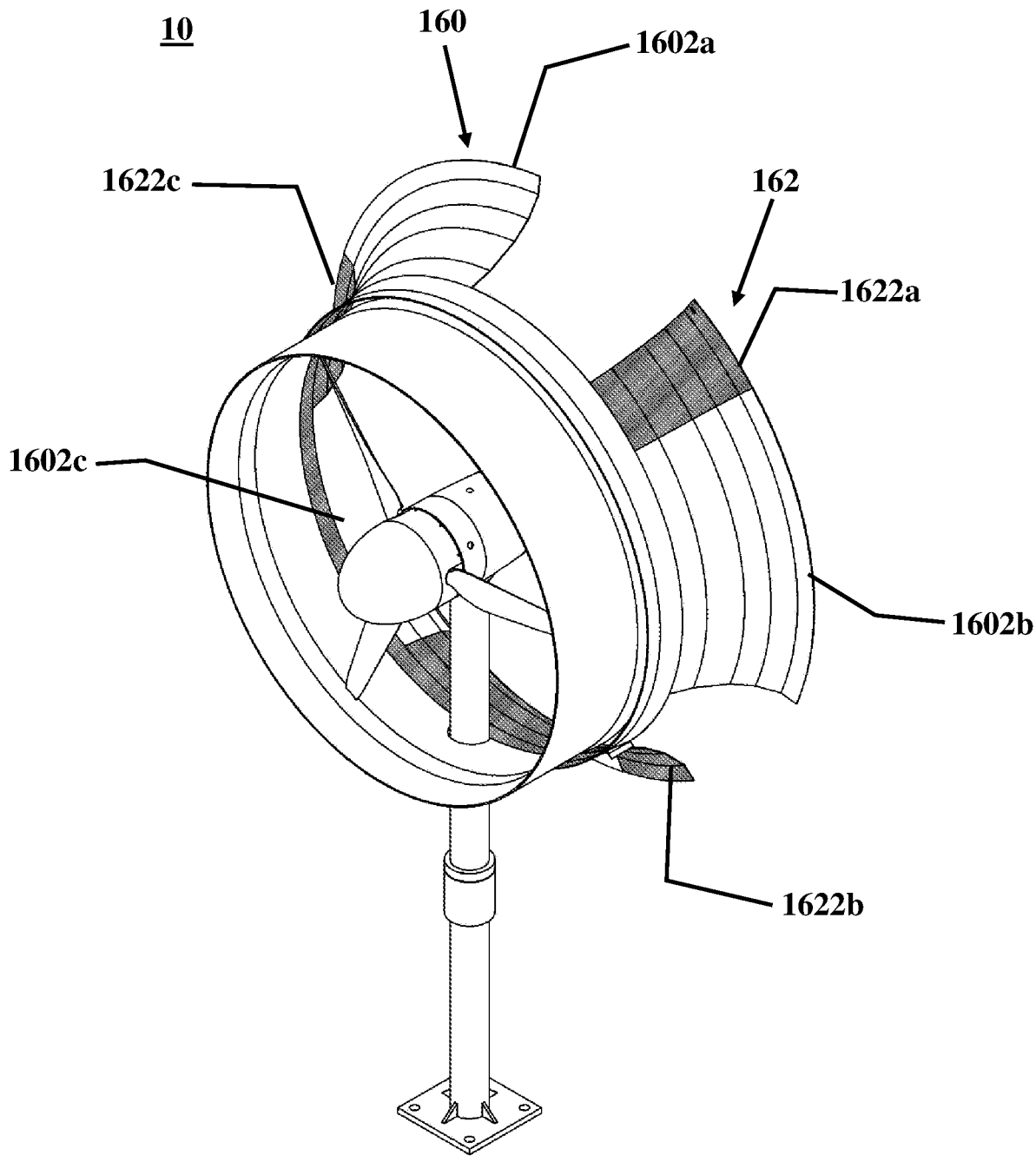


FIG. 2B

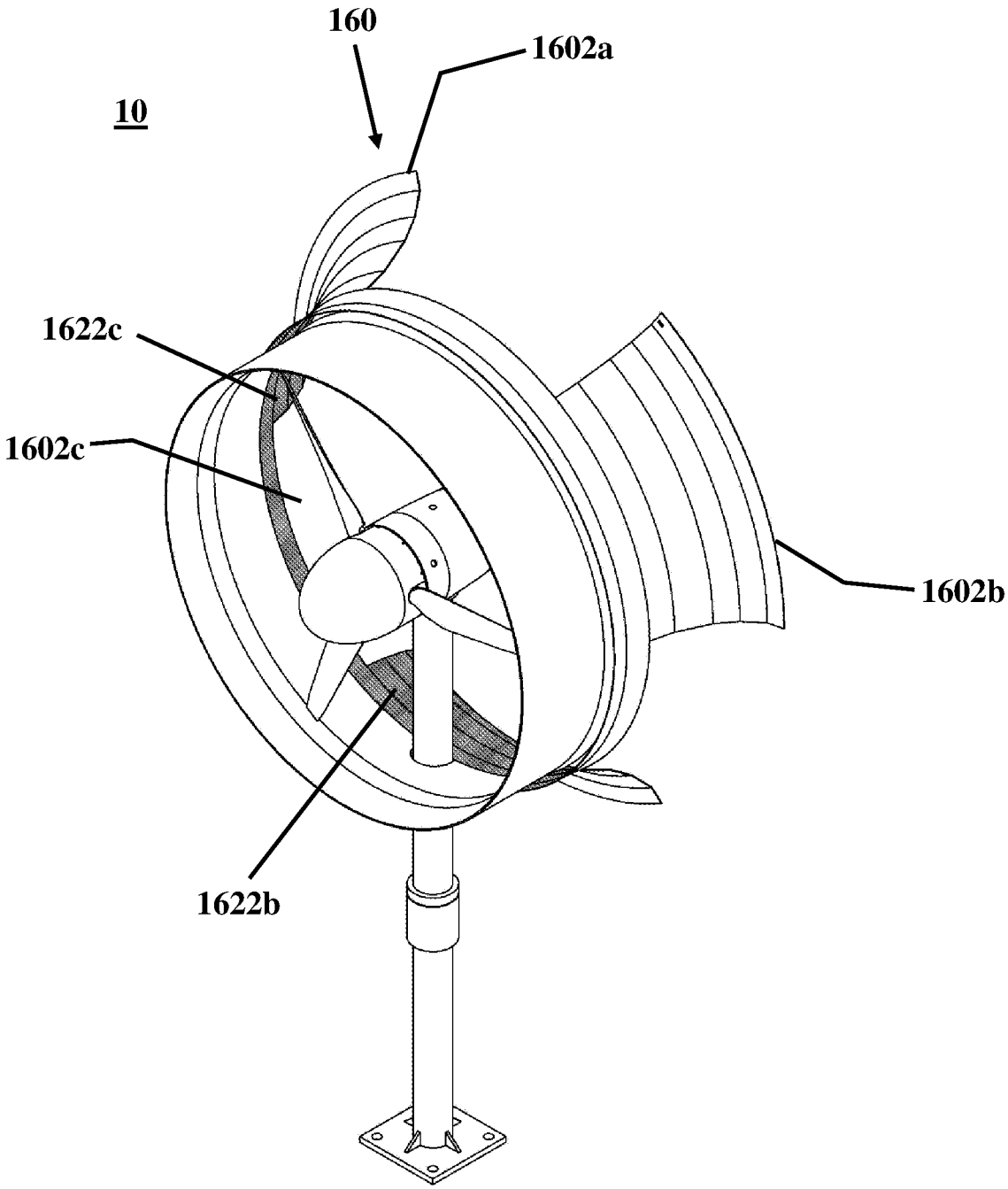


FIG. 2C

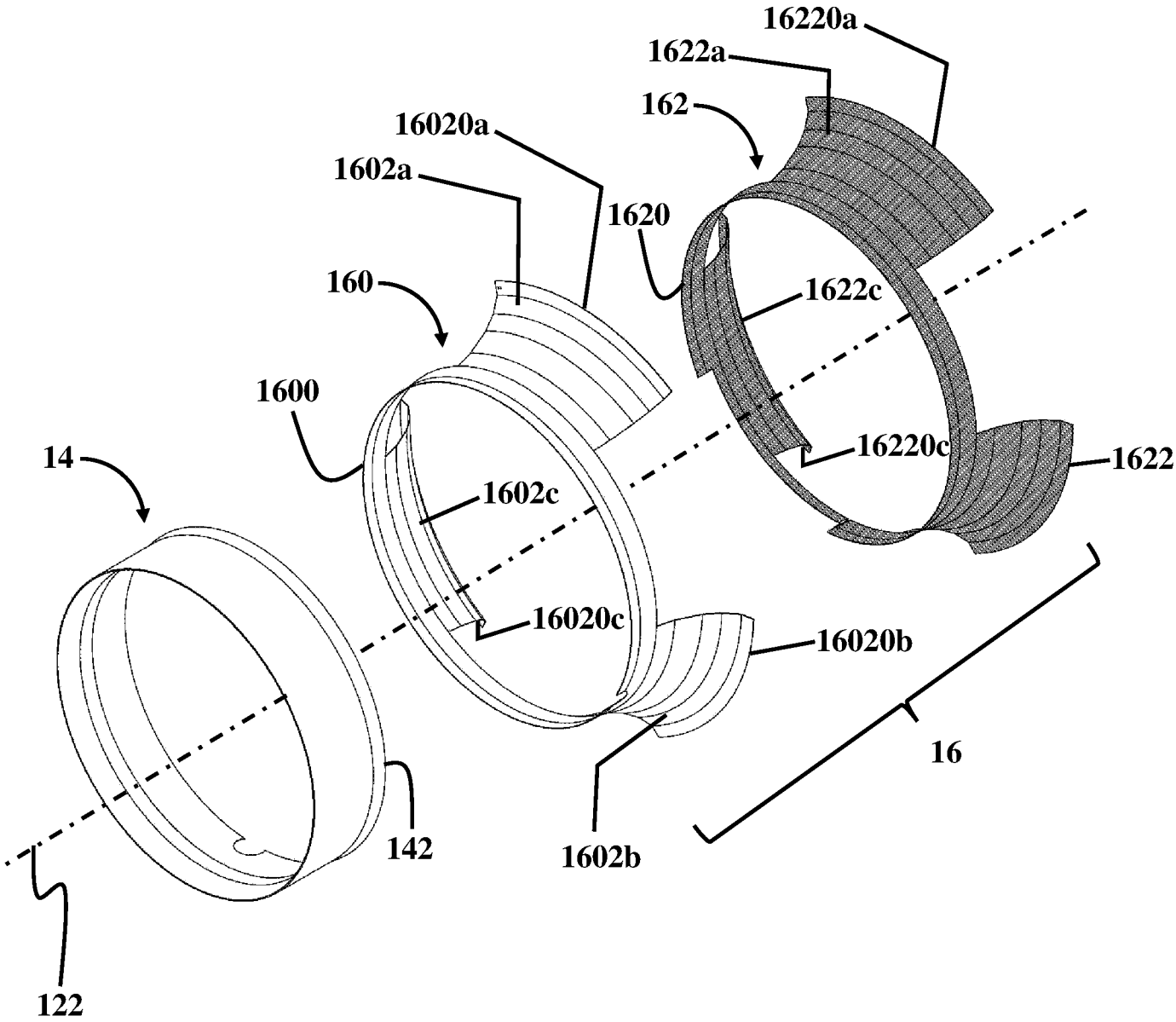

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1602b
122

FIG. 3A

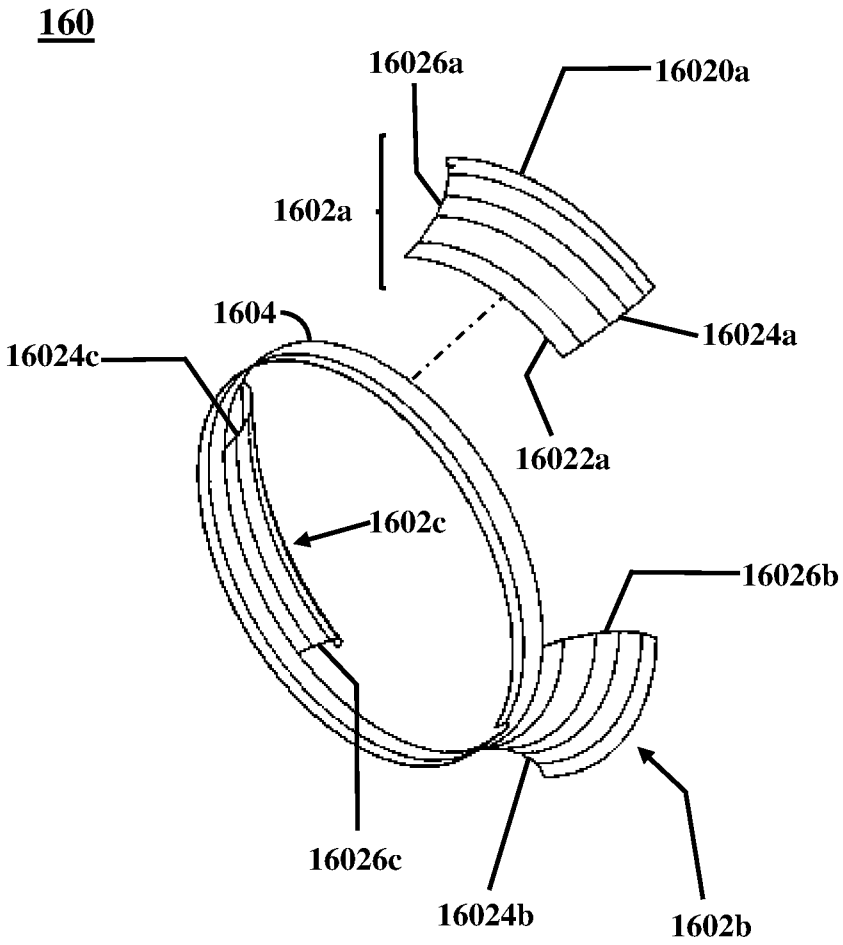

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16026c
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1602b

FIG. 3B

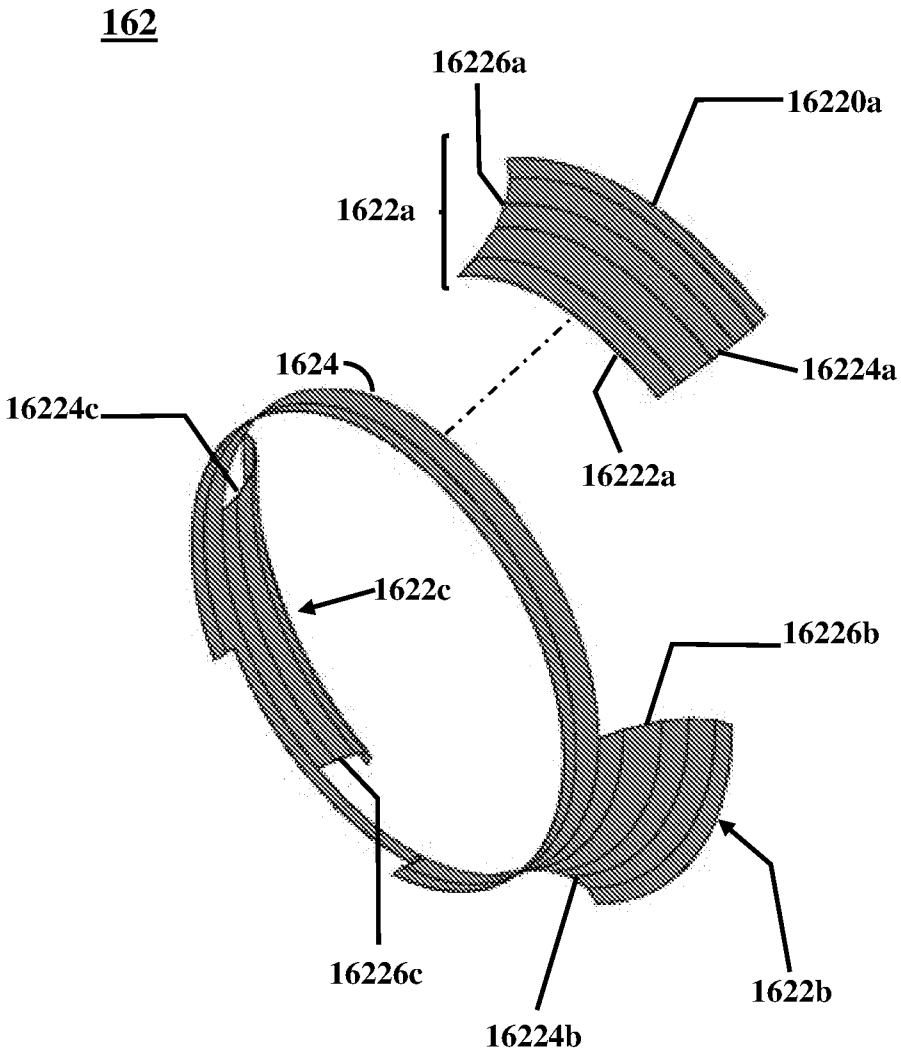

162
16226a
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FIG. 3C

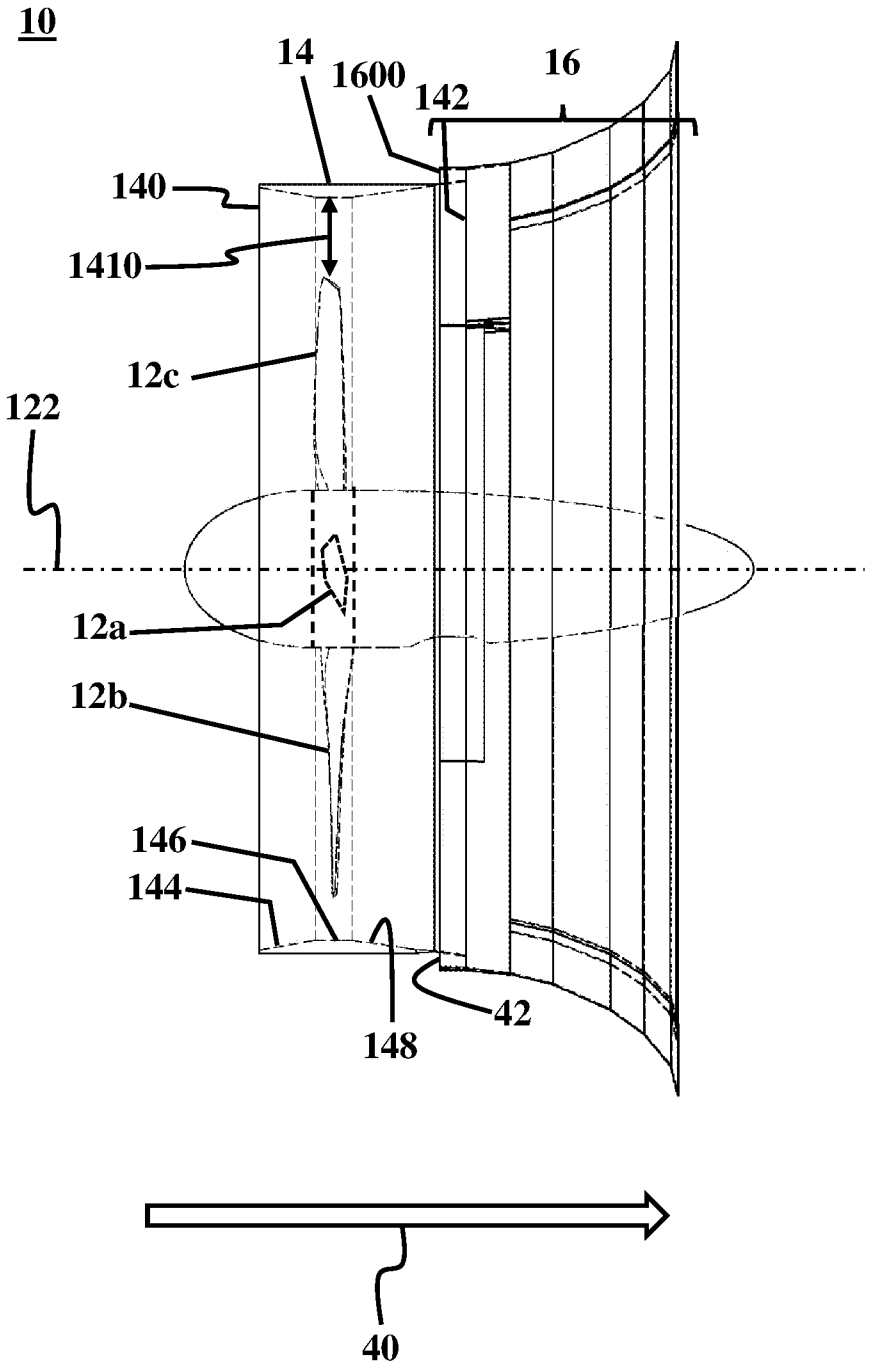


FIG. 4A

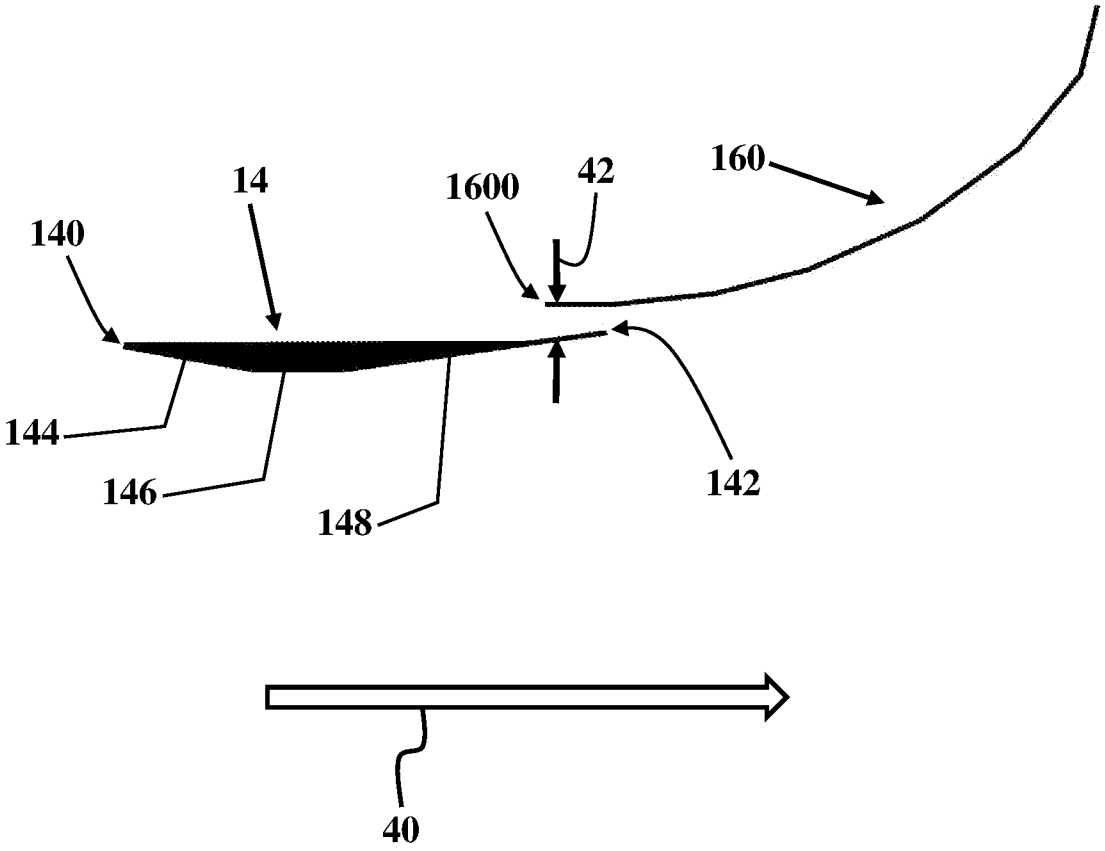


FIG. 4B

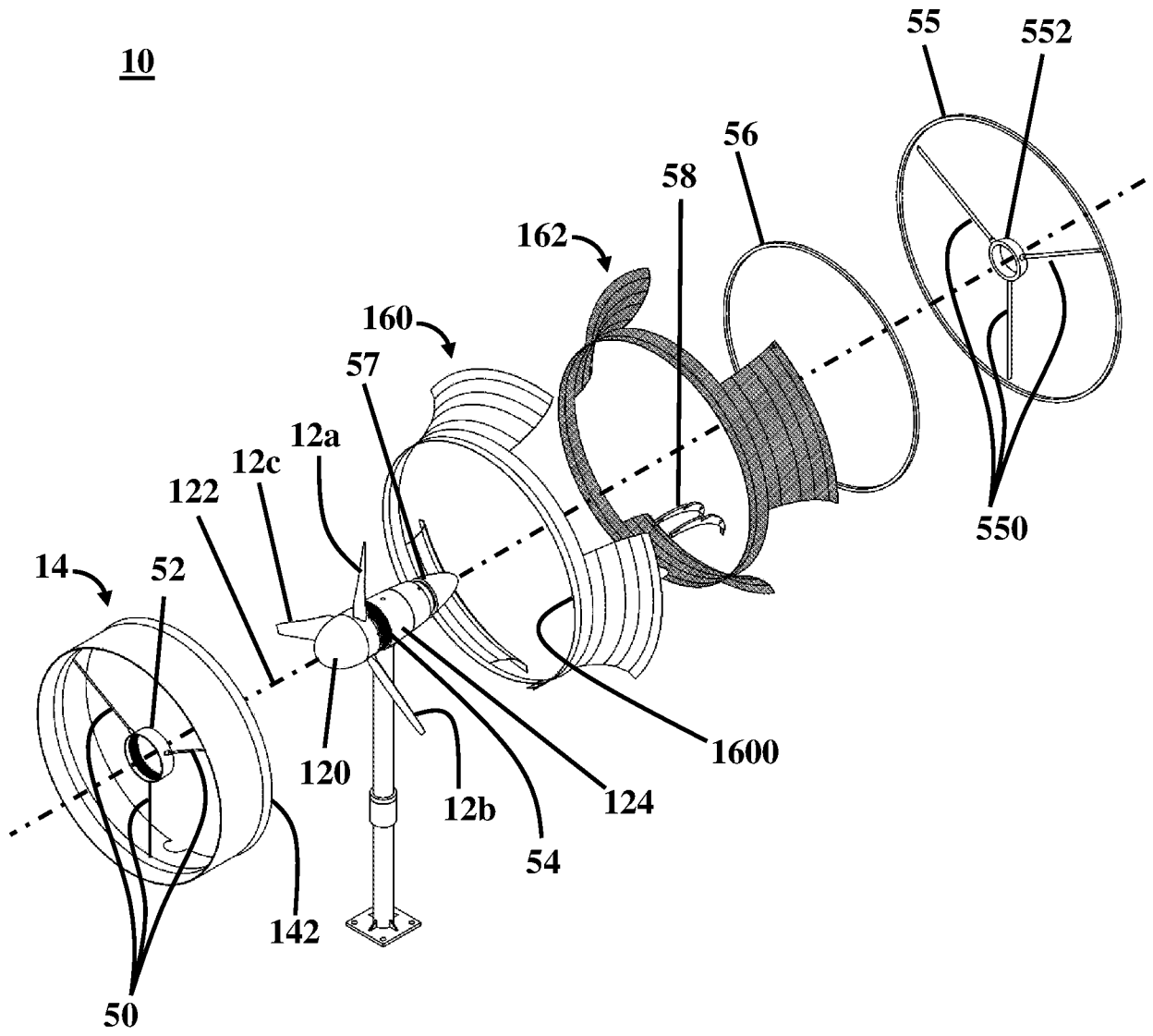

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FIG. 5

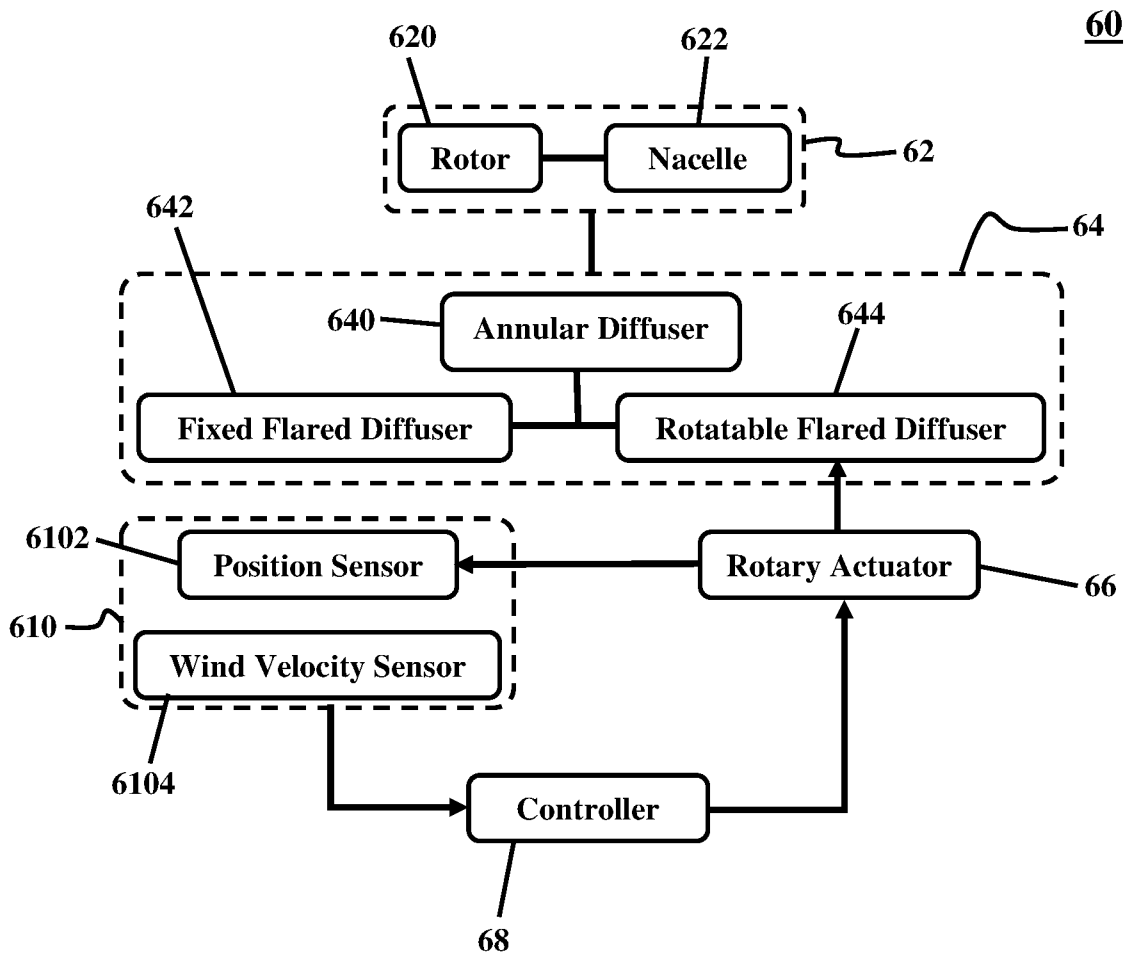

60
620
622
Rotor
Nacelle
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640
Annular Diffuser
644
Fixed Flared Diffuser
Rotatable Flared Diffuser
6102
Position Sensor
Rotary Actuator
66
610
Wind Velocity Sensor
6104
Controller
68

FIG. 6

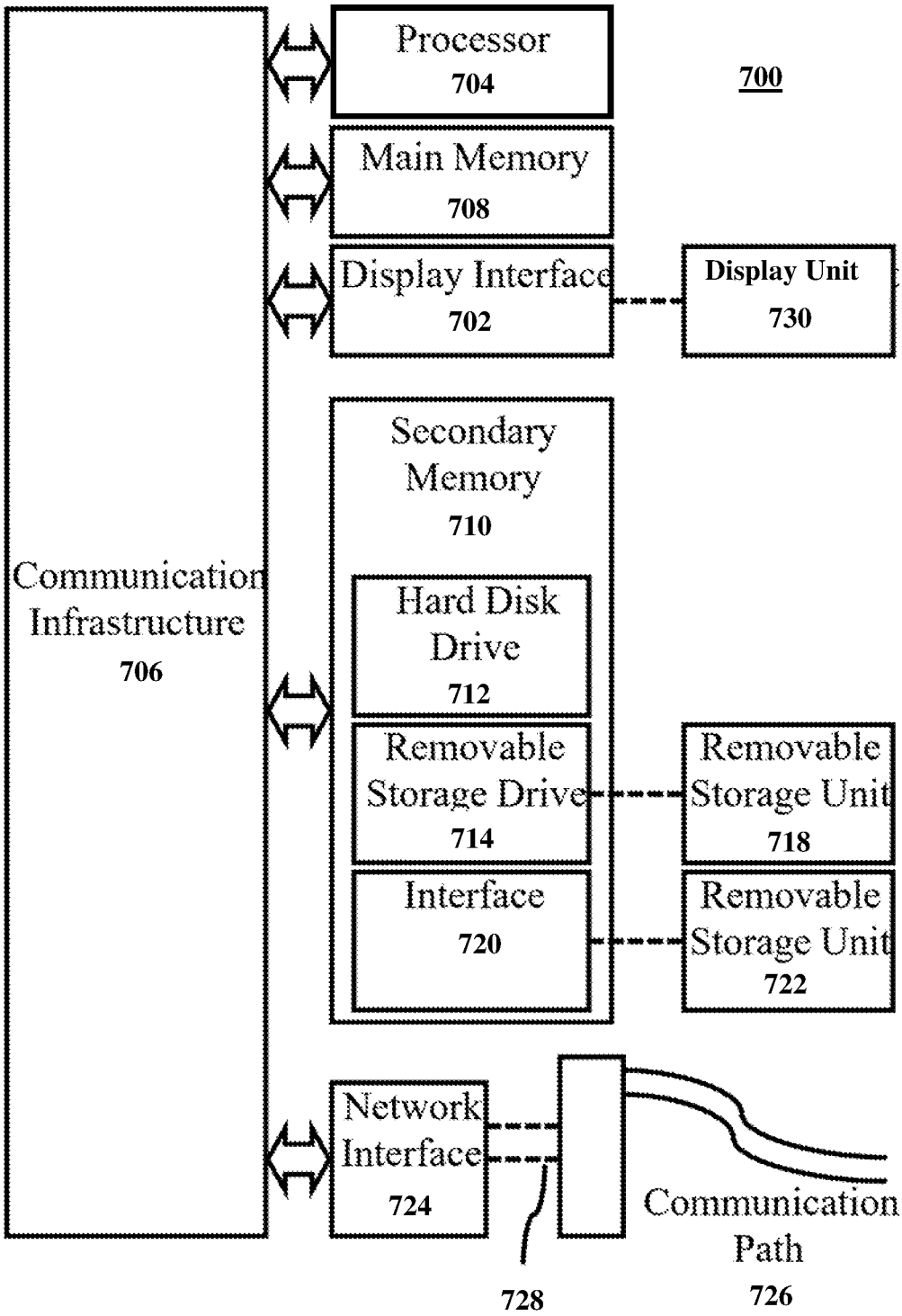

Processor
704
700
Main Memory
708
Display Interface
702
Display Unit
730
Secondary Memory
710
Communication Infrastructure
706
Hard Disk Drive
712
Removable Storage Drive
714
Removable Storage Unit
718
Interface
720
Removable Storage Unit
722
Network Interface
724
Communication Path
726
728

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2020/056306

A. CLASSIFICATION OF SUBJECT MATTER
F03D1/04 Version=2020.01

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F03D1/04

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

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

TotalPatent One, IPO Internal Database
Keywords: Diffuser, turbine, augment*, flared, petal, nacelle, sensor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 9567970 B2 (ANAKATA WIND POWER RESOURCES S A R L (CH) Et al.) 14 February 2017 (14.02.2017) Abstract, Col. 3, lines 15-31, Col. 6, lines 27-28, Col. 9, lines 43-54, Claim 1	1, 6-8, 10
Y	Col. 5, lines 25-27, Col. 11, lines 17-19, Fig. 1	2-5, 9, 11-13
Y	WO 2009130730 A1 (FARRELLY FRANCIS ALLEN (IT)) 29 October 2009 (29.10.2009) Page 2, lines 5-9, Page 3, lines 4-8, Claim 1	4, 5, 9, 11
Y	US 10294913 B2 (HYDROKINETIC ENERGY CORP (US) Et al.) 21 May 2019 (21.05.2019) Col. 17, lines 4-6	2, 3
Y	KR 1020120113878 A (HYUNDAI HEAVY INDUSTRIES CO., LTD. (KR)) 16 October 2012 (16.10.2012) Para. 0017, 0019 and 0027 & NO FAMILY	12, 13

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16-10-2020	16-10-2020
Name and mailing address of the ISA/ Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Authorized officer Atul Raj Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2020/056306

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