

(43) **Pub. Date:** **Jul. 18, 2013**

A flange connection for two tower sections of a wind energy system is described. The wind energy system includes a first flange including a first portion and a second portion, and a second flange including a first portion and a second portion. The wind energy system further includes a first connecting element having substantially the shape of at least a segment of a ring and a second connecting element having substantially the shape of at least a segment of a ring. The first connecting element and the second connecting element are adapted for being connected to each other and are adapted for connecting the first portion of the first flange with the first portion of the second flange.

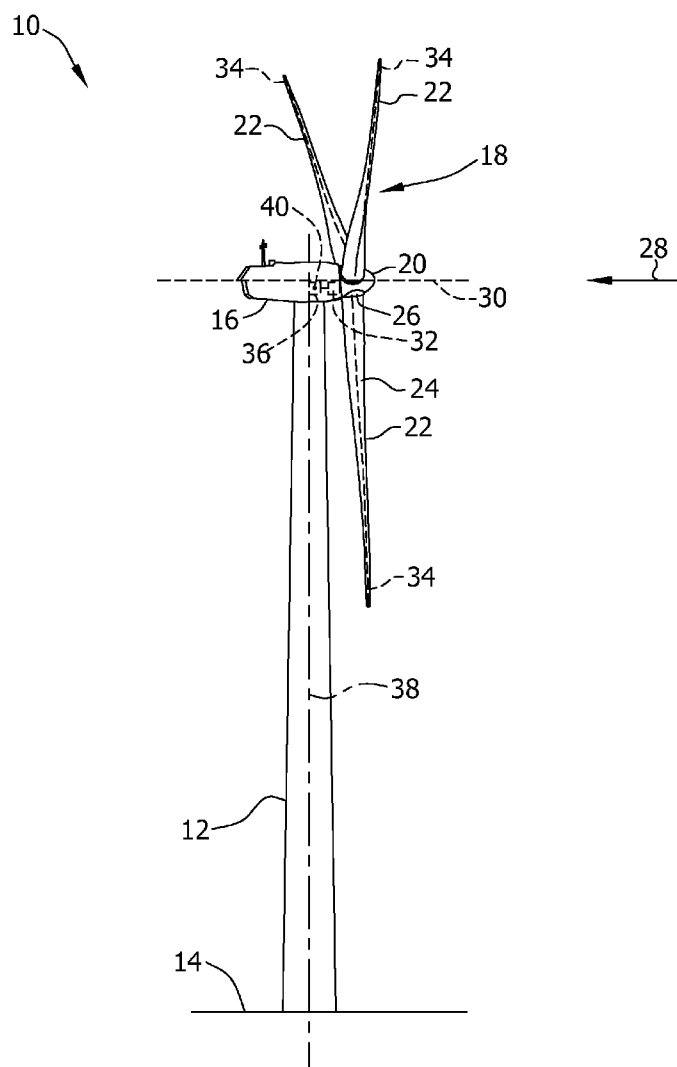


FIG. 1

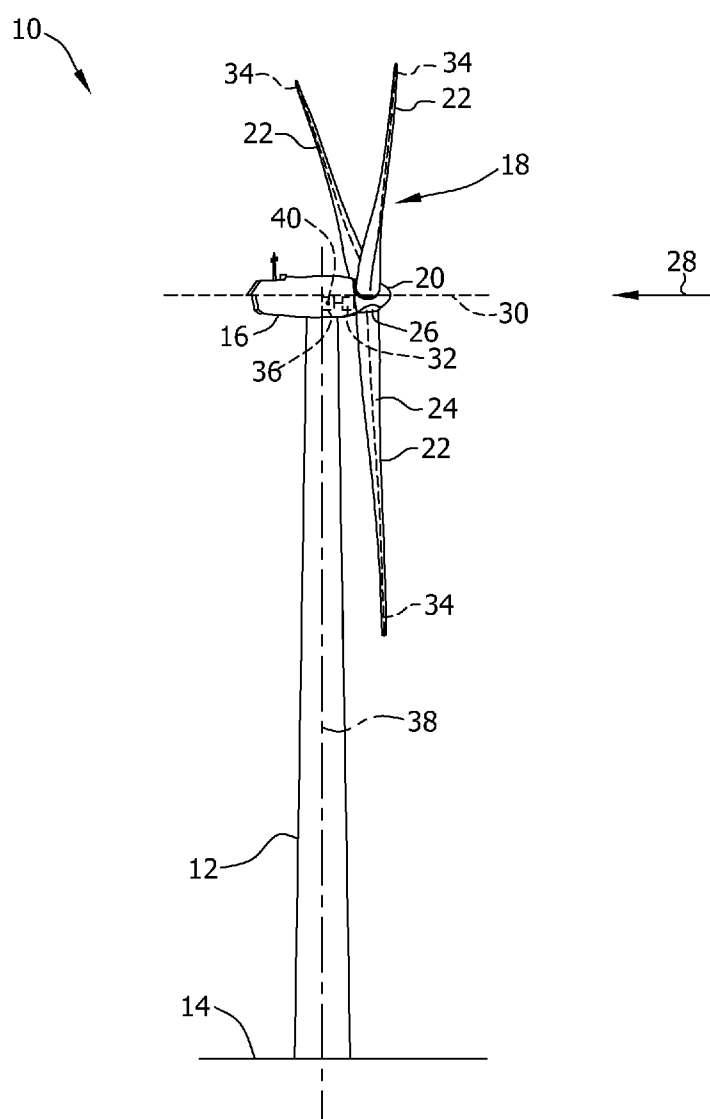
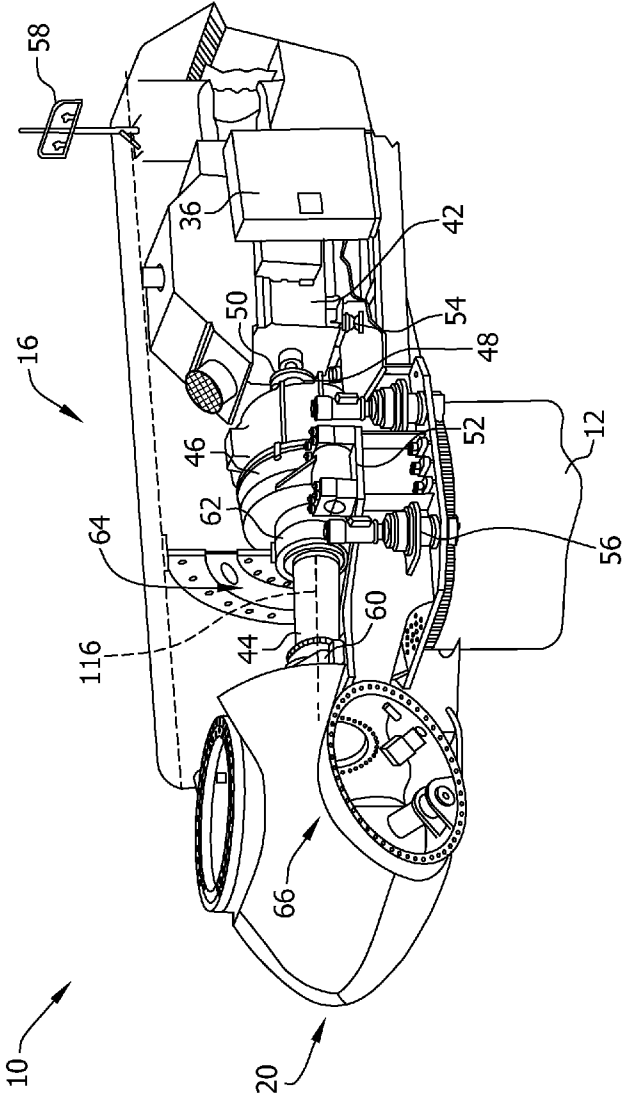


FIG. 2



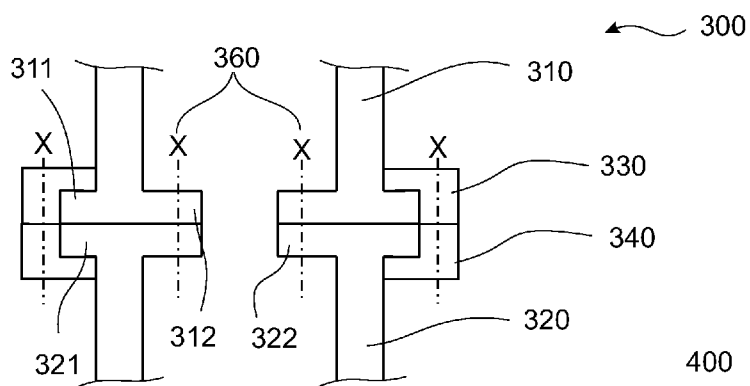


FIG. 3

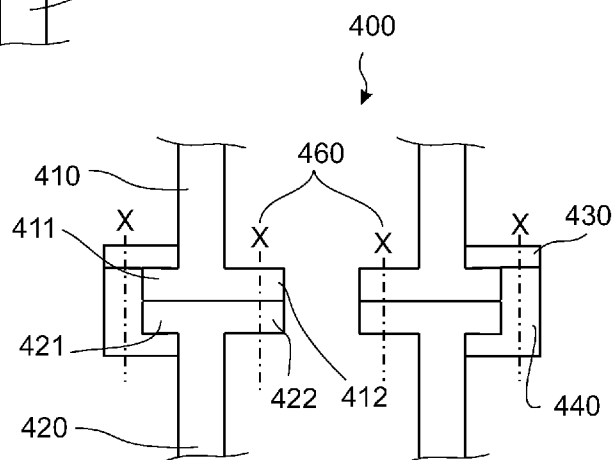


FIG. 4

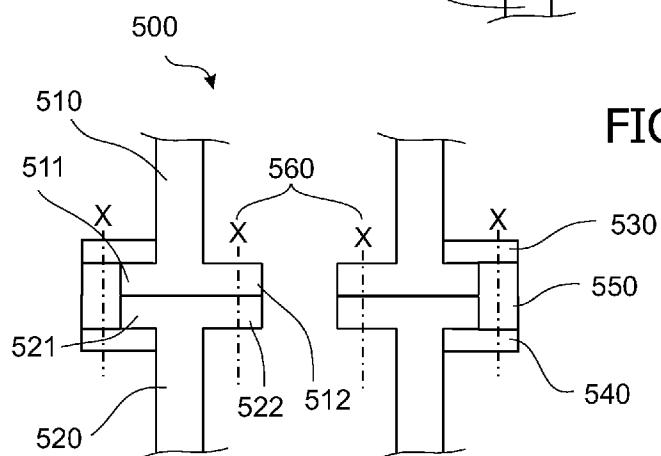


FIG. 5

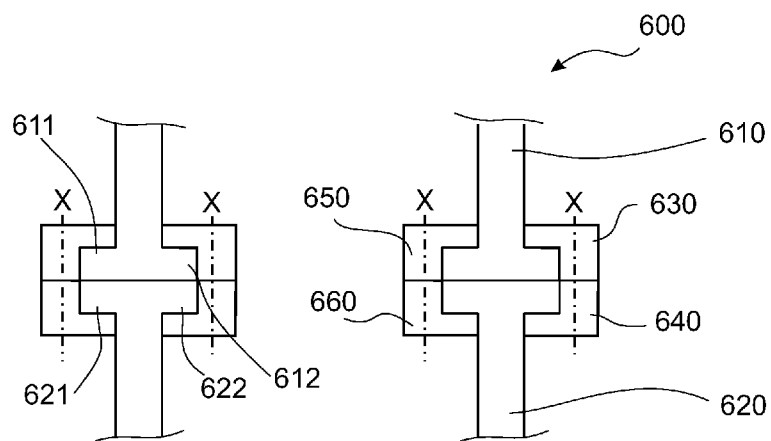


FIG. 6

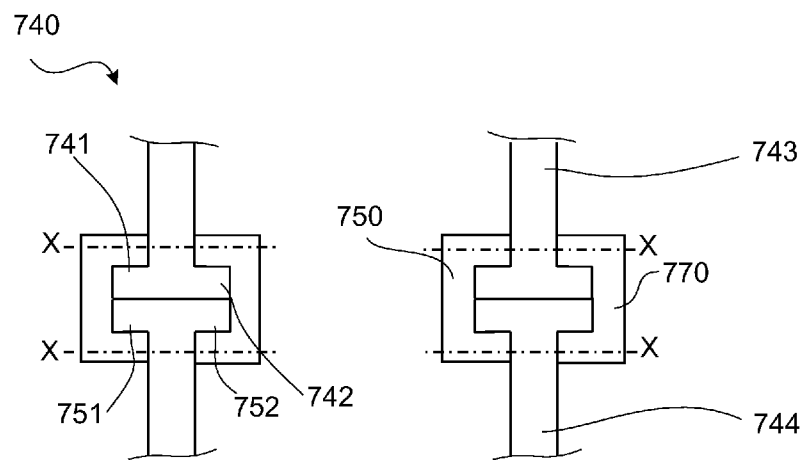


FIG. 7

FIG. 8

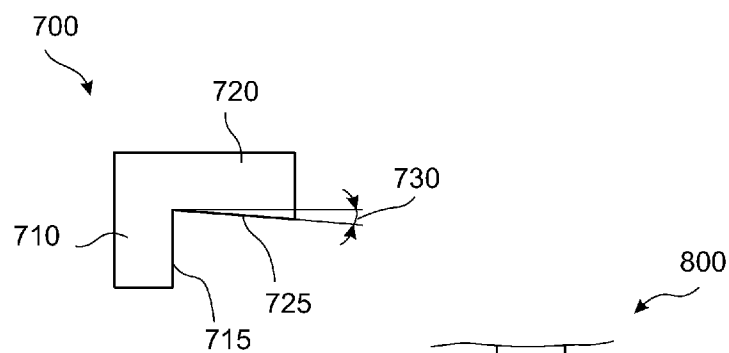
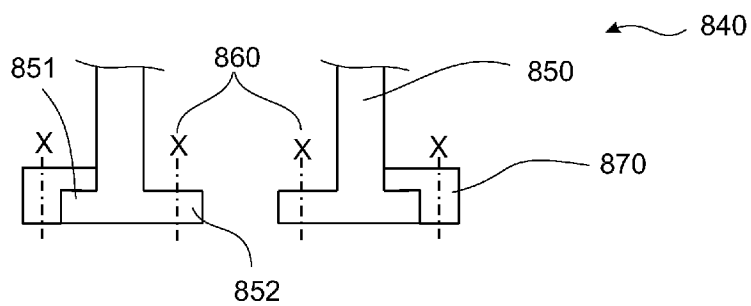


FIG. 9

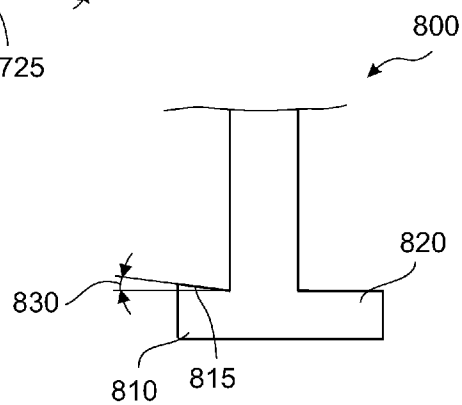


FIG. 10

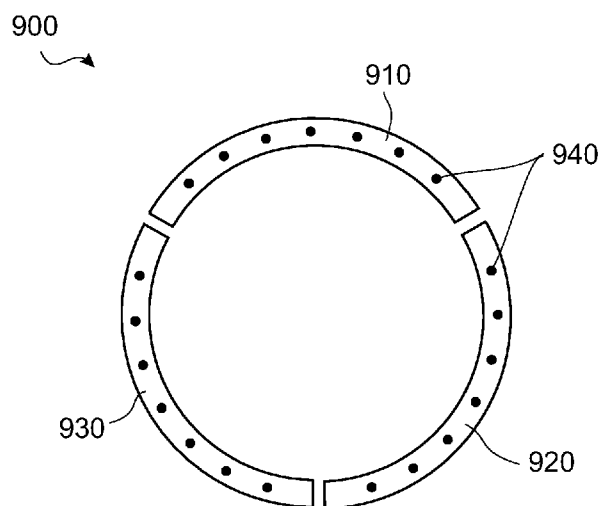


FIG. 11

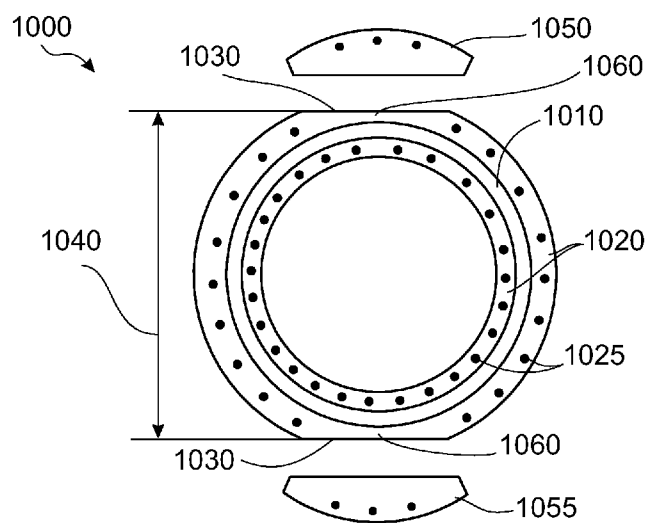


FIG. 12

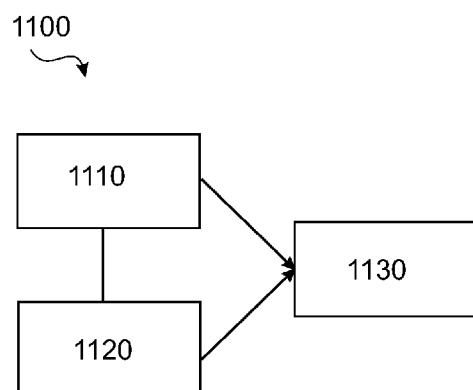


FIG. 13

FLANGE CONNECTION FOR A WIND TURBINE AND METHOD OF CONNECTING PARTS OF A WIND TURBINE

BACKGROUND OF THE INVENTION

[0001] The subject matter described herein relates generally to methods and systems for flange connections, and more particularly, to methods and systems for flange connections in a wind turbine.

[0002] At least some known wind turbines include a tower and a nacelle mounted on the tower. A rotor is rotatable mounted to the nacelle and is coupled to a generator by a shaft. A plurality of blades extends from the rotor. The blades are oriented such that wind passing over the blades turns the rotor and rotates the shaft, thereby driving the generator to generate electricity.

[0003] Wind turbines are placed at locations providing high wind amounts. However, as the conditions are often rough at the wind turbine locations and as the wind turbines become larger, the tower of the wind turbine is subject to heavy stresses. Thus, the wind turbine tower is constructed in a stable way, including an appropriate diameter for carrying the nacelle and withstanding the rough conditions.

[0004] Due to the increasing size of the wind turbine tower, the tower is segmented in several parts so as to facilitate the transport of the wind turbine tower to the wind turbine location. The several parts of the wind turbine tower are mounted and connected to each other at the wind turbine location.

[0005] When several parts of a wind turbine tower are provided and mounted, the parts are connected by flange connections in order to ensure the required strength of the connections. However, the strong flange connections of the wind turbine tower parts are often space consuming, increase the diameter of the tower segment and consequently the transport costs.

[0006] Thus, there is a desire to provide a strong flange connection for wind turbine parts, while taking into account the transport costs at the same time.

BRIEF DESCRIPTION OF THE INVENTION

[0007] In one aspect, a connection for a wind energy system is provided. Typically, the wind energy system includes a first flange including a first portion and a second portion, and a second flange including a first portion and a second portion. The wind energy system may further include a first connecting element having substantially the shape of at least a segment of a ring and a second connecting element having substantially the shape of at least a segment of a ring. The first connecting element and the second connecting element may be adapted for being connected to each other and may be adapted for connecting the first portion of the first flange with the first portion of the second flange.

[0008] In another aspect, a wind energy system is provided. Typically, the wind energy system includes a nacelle including a rotor; a tower carrying the nacelle; a flange on at least a part of the tower, wherein the flange includes a first portion and a second portion extending in a substantially horizontal direction. Further the wind energy system includes a connecting element having substantially the shape of at least a segment of a ring, wherein the connecting element is adapted for being placed on the first portion of the flange and is adapted for securing at least a part of the tower.

[0009] In yet another aspect, a tower section of a wind energy system is provided. The tower section may include a flange on at least a part of the tower section. Typically, the flange includes a first portion and a second portion extending in a substantially horizontal direction. Further, the tower section may include a connecting element having substantially the shape of at least a segment of a ring, wherein the connecting element is placed on the first portion of the flange and is adapted for securing the tower section.

[0010] Further aspects, advantages and features of the present invention are apparent from the dependent claims, the description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A full and enabling disclosure including the best mode thereof, to one of ordinary skill in the art, is set forth more particularly in the remainder of the specification, including reference to the accompanying figures wherein:

[0012] FIG. 1 is a perspective view of an exemplary wind turbine.

[0013] FIG. 2 is an enlarged sectional view of a portion of the wind turbine shown in FIG. 1.

[0014] FIG. 3 is a schematic drawing of a flange connection according to embodiments described herein.

[0015] FIG. 4 is a schematic drawing of a flange connection according to embodiments described herein.

[0016] FIG. 5 is a schematic drawing of a flange connection according to embodiments described herein.

[0017] FIG. 6 is a schematic drawing of a flange connection according to embodiments described herein.

[0018] FIG. 7 is a schematic drawing of a flange connection according to embodiments described herein.

[0019] FIG. 8 is a schematic drawing of a tower section according to embodiments described herein.

[0020] FIG. 9 is a schematic drawing of a collar flange according to embodiments described herein.

[0021] FIG. 10 is a schematic drawing of a flange according to embodiments described herein.

[0022] FIG. 11 is a schematic top view of a collar flange according to embodiments described herein.

[0023] FIG. 12 is a cross-sectional view of a wind energy tower flange assembly according to embodiments described herein.

[0024] FIG. 13 is a schematic flow chart of a method for connecting parts of a wind turbine according to embodiments described herein.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in each figure. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet further embodiments. It is intended that the present disclosure includes such modifications and variations.

[0026] The embodiments described herein include a wind turbine system that includes a flange connection having the required strength, whilst at the same time saving transport and manufacturing costs. More specifically, the flange assembly as described herein provides a way to assemble a flange (such as a T-flange) in order to overcome transportation limits. Further, the flanges according to embodiments described

herein are easy to transport as well as easy to assemble by providing multiple split parts across the circumference.

[0027] As used herein, the term flange is intended to be representative of a connecting element for connecting parts. The parts to be connected may be in the shape of a tube, a ring, a substantially circular device or the like. According to some embodiments, the parts to be connected may include non circular shapes like triangular, pentagonal or multifaceted shapes. The connecting element may be adapted to be used in wind energy systems, such as for connecting parts of the tower of a wind energy system. According to some embodiments, the flange may be used to connect parts of a tower. Typically, a flange connection as used herein may refer to a connection including a flange. For instance, a flange connection may include two flanges to be connected to each other. According to some embodiments, the flange connection may include two flanges to be connected with each other and further connecting components or elements. The flange as described herein may be used in wind energy systems, but may also be applicable for other technologies using flanges.

[0028] The term “at least a segment of a ring” as used herein is intended to be representative of a ring-like device, which may be a whole ring or a segment of a ring. Typically, the segment of the ring may include a defined angle, which may be dependent on the respective application. For instance, the angle of a ring segment may be about 5°, about 30°, about 300° or any value between, above or below these examples. According to some embodiments, having “substantially” the shape of a ring means that a certain deviation from the ring-shape may be provided. For instance, the device having “substantially a ring shape” may not have a circular ring shape, but another shape, such as an elliptic shape, a partly circular shape or the like.

[0029] Typically, the term “connecting” in this context refers to fastening one or more parts to one or more different parts. For instance, connecting two parts may refer to fastening or fixing these two parts to each other. According to some embodiments, further components, such as bolts or screws, may be used for connecting parts together.

[0030] As used herein, the term “blade” is intended to be representative of any device that provides a reactive force when in motion relative to a surrounding fluid. As used herein, the term “wind turbine” is intended to be representative of any device that generates rotational energy from wind energy, and more specifically, converts the kinetic energy of wind into mechanical energy. As used herein, the term “wind generator” is intended to be representative of any wind turbine that generates electrical power from rotational energy generated from wind energy, and more specifically, converts mechanical energy converted from kinetic energy of wind to electrical power.

[0031] FIG. 1 is a perspective view of an exemplary wind turbine 10. In the exemplary embodiment, wind turbine 10 is a horizontal-axis wind turbine. Alternatively, wind turbine 10 may be a vertical-axis wind turbine. In the exemplary embodiment, wind turbine 10 includes a tower 12 that extends from a support system 14, a nacelle 16 mounted on tower 12, and a rotor 18 that is coupled to nacelle 16. Rotor 18 includes a rotatable hub 20 and at least one rotor blade 22 coupled to and extending outward from hub 20. In the exemplary embodiment, rotor 18 has three rotor blades 22. In an alternative embodiment, rotor 18 includes more or less than three rotor blades 22. In the exemplary embodiment, tower 12 is fabricated from tubular steel to define a cavity (not shown in

FIG. 1) between support system 14 and nacelle 16. In an alternative embodiment, tower 12 is any suitable type of tower having any suitable height.

[0032] Rotor blades 22 are spaced about hub 20 to facilitate rotating rotor 18 to enable kinetic energy to be transferred from the wind into usable mechanical energy, and subsequently, electrical energy. Rotor blades 22 are mated to hub 20 by coupling a blade root portion 24 to hub 20 at a plurality of load transfer regions 26. Load transfer regions 26 have a hub load transfer region and a blade load transfer region (both not shown in FIG. 1). Loads induced to rotor blades 22 are transferred to hub 20 via load transfer regions 26.

[0033] In one embodiment, rotor blades 22 have a length ranging from about 15 meters (m) to about 91 m. Alternatively, rotor blades 22 may have any suitable length that enables wind turbine 10 to function as described herein. For example, other non-limiting examples of blade lengths include 10 in or less, 20 in, 37 in, or a length that is greater than 91 m. As wind strikes rotor blades 22 from a direction 28, rotor 18 is rotated about an axis of rotation 30. As rotor blades 22 are rotated and subjected to centrifugal forces, rotor blades 22 are also subjected to various forces and moments. As such, rotor blades 22 may deflect and/or rotate from a neutral, or non-deflected, position to a deflected position.

[0034] In the exemplary embodiment, control system 36 is shown as being centralized within nacelle 16, however, control system 36 may be a distributed system throughout wind turbine 10, on support system 14, within a wind farm, and/or at a remote control center. Control system 36 includes a processor 40 configured to perform the methods and/or steps described herein. Further, many of the other components described herein include a processor. As used herein, the term “processor” is not limited to integrated circuits referred to in the art as a computer, but broadly refers to a controller, a microcontroller, a microcomputer, a programmable logic controller (PLC), an application specific integrated circuit, and other programmable circuits, and these terms are used interchangeably herein. It should be understood that a processor and/or a control system can also include memory, input channels, and/or output channels.

[0035] In the embodiments described herein, memory may include, without limitation, a computer-readable medium, such as a random access memory (RAM), and a computer-readable non-volatile medium, such as flash memory. Alternatively, a floppy disk, a compact disc-read only memory (CD-ROM), a magneto-optical disk (MOD), and/or a digital versatile disc (DAM) may also be used. Also, in the embodiments described herein, input channels include, without limitation, sensors and/or computer peripherals associated with an operator interface, such as a mouse and a keyboard. Further, in the exemplary embodiment, output channels may include, without limitation, a control device, an operator interface monitor and/or a display.

[0036] Processors described herein process information transmitted from a plurality of electrical and electronic devices that may include, without limitation, sensors, actuators, compressors, control systems, and/or monitoring devices. Such processors may be physically located in, for example, a control system, a sensor, a monitoring device, a desktop computer, a laptop computer, a programmable logic controller (PLC) cabinet, and/or a distributed control system (DCS) cabinet. RAM and storage devices store and transfer information and instructions to be executed by the processor (s). RAM and storage devices can also be used to store and

provide temporary variables, static (i.e., non-changing) information and instructions, or other intermediate information to the processors during execution of instructions by the processor(s). Instructions that are executed may include, without limitation, wind turbine control system control commands. The execution of sequences of instructions is not limited to any specific combination of hardware circuitry and software instructions.

[0037] FIG. 2 is an enlarged sectional view of a portion of wind turbine 10. In the exemplary embodiment, wind turbine 10 includes nacelle 16 and hub 20 that is rotatable coupled to nacelle 16. More specifically, hub 20 is rotatable coupled to an electric generator 42 positioned within nacelle 16 by rotor shaft 44 (sometimes referred to as either a main shaft or a low speed shaft), a gearbox 46, a high speed shaft 48, and coupling 50. In the exemplary embodiment, rotor shaft 44 is disposed coaxial to longitudinal axis 116. Rotation of rotor shaft 44 rotatable drives gearbox 46 that subsequently drives high speed shaft 48. High speed shaft 48 rotatable drives generator 42 with coupling 50 and rotation of high speed shaft 48 facilitates production of electrical power by generator 42. Gearbox 46 and generator 42 are supported by a support 52 and a support 54. In the exemplary embodiment, gearbox 46 utilizes dual path geometry to drive high speed shaft 48. Alternatively, rotor shaft 44 is coupled directly to generator 42 with coupling 50.

[0038] Nacelle 16 also includes a yaw drive mechanism 56 that may be used to rotate nacelle 16 and hub 20 on yaw axis 38 (shown in FIG. 1) to control the perspective of rotor blades 22 with respect to direction 28 of the wind. Nacelle 16 also includes at least one meteorological mast 58 that includes a wind vane and anemometer (neither shown in FIG. 2). Mast 58 provides information to control system 36 that may include wind direction and/or wind speed. In the exemplary embodiment, nacelle 16 also includes a main forward support bearing 60 and a main aft support bearing 62.

[0039] According to some embodiments, the tower of a wind turbine may be divided in several parts so as to facilitate the transport and mounting of the wind turbine tower. For instance, the parts or sections being mounted to form the wind turbine tower may have a diameter of about 4 m (such as 4.3 m) and a height in a range of about 10 m to about 25 m (such as in a range from about 12 m to about 24 m). The parts of a wind turbine tower may be connected by a flange connection. Typically, T-flange constructions are proved to be more effective arrangements compared to L-flange arrangements. T-flanges are able to transfer larger moments than L-flanges, which gives a benefit for larger MW rating machines. However, T-flange assemblies providing a larger outer diameter than L-flanges suffer from a drawback concerning transportation costs when used in large wind turbines. A limitation of existing L-flange design is, for instance, the number of bolts which is limited due to space constraints. With increasing hub height and MW rating of the wind turbine, the tower base loads tend to increase continuously. A single row of bolts, as for instance used in L-flanges, is not adequate for high tower base moments, which is proved by analysis. It has also been found that having an L-flange configuration with two rows of bolts is inefficient and improves the moment transfer capacity of the joint only marginally. Also, an increasing number of bolts, an increasing size of the bolts and/or an increasing width of the flange cannot deliver the desired properties. Furthermore, increasing the tower base diameter by dividing the tower base in the circumferential direction in order to

meet the transportation limits causes undesired side-effects. When compared with the L-flange design, the T-flange design has a high bearing moment due to the equal sharing of loads by both rows of bolts, but transportation limits often prevent an integral T-joint from being used.

[0040] The flange assembly according to embodiments described herein concerns connecting tower sections using collar flanges. In embodiments of the invention, the existing L-flanges are provided with a collar of small width on the outer surface to provide a mounting interface for a collar flange. Collar flanges having two halves may be mounted on the respective collar of the tower sections. Typically, the flanges of the flange assembly described herein may be mounted to a tower section (such as welded to a tower section) or may be a part of the tower section.

[0041] Typically, in a flange assembly according to embodiments described herein, a collar flange is assembled to an L-flange, whereby an outer row of bolts provided at the collar flange provide the required clamping force. Typically, the outer row of bolts of the collar flange together with the inner row of bolts of the L-flange act as a T-flange. The joint connection is able to transfer high bending moments. Typically, joints for larger MW machines allow designing within transportation limits. The flange connection according to embodiments described herein help in facilitating the transport and assembly of the wind turbine parts. Typically, an outer row of bolts are easily accessible for maintenance since the proposed joint is a tower base ring (TBR) to the tower door section interface.

[0042] FIG. 3 shows an embodiment of a flange connection according to embodiments described herein. Typically, the flange connection 300 provides a first flange 310 and a second flange 320. According to some embodiments, the first flange 310 may include a first portion 311 and a second portion 312. Typically also the second flange 320 may include a first portion 321 and a second portion 322. Generally, the first and the second portion 311 and 312 of the first flange 310 and the first and the second portion 321 and 322 of the second flange 320 may extend substantially in the horizontal direction.

[0043] The term “substantially” as used herein may mean that there may be a certain deviation from the characteristic denoted with “substantially.” For instance, the term “substantially horizontal” refers to a direction which may have certain deviations from the exact horizontal position, such as a deviation of about 1° to 15° of the horizontal direction. According to a further example, the term “having substantially an L-shape” may refer to the shape of an element in a cross-sectional view. For instance, an element may have substantially the form of an L, when two parts of the element are present having a certain angle between them. Typically, the angle between the parts of the element may be between 70° and 100°. Further, according to one embodiment, one of the parts of the element denoted as having an L-shape may be shorter than the other. According to yet a further example, the term “having substantially the shape of a plate” may refer to a case, where an element is formed so as to be planar. Typically, the plate may deviate from the planar arrangement to a certain extent.

[0044] As can be seen in FIG. 3, the flange connection 300 also includes a first connecting element 330 and a second connecting element 340. Typically, the first and second connecting elements are provided in a ring-like shape or at least as a segment of a ring-like shape, as will be explained in detail below.

[0045] According to some embodiments, which can be combined with other embodiments described herein, the first connecting element and the second connecting element may be adapted to be connected to each other. Typically, the first connecting element and the second connecting element may be adapted to connect the first portion of the first flange to the first portion of the second flange.

[0046] Typically, the first portion of a flange as described herein may also be referred to as a collar of the flange. Further, according to some embodiments, the first and the second connecting element as described herein may also be denoted as collar flanges.

[0047] Typically, the flange connection according to embodiments described herein is assembled so as to obey transportation limits. According to some embodiments, an L-flange is assembled into a T-flange by providing a collar extension to the L-flange, wherein the extension of the collar in the horizontal direction is smaller than the extension of a T-flange in the respective direction. For instance, the extension of the collar of the flange in the horizontal direction may typically range from about 50 mm to about 200 mm, more typically from about 70 mm to about 150 mm, and even more typically from about 90 mm to about 110 mm. According to one embodiment, which can be combined with other embodiments described herein, the extension of the collar of the flange in the horizontal direction may be about 100 mm.

[0048] According to some embodiments, the connecting elements, such as collar flanges described herein, may be made from a substantially rigid or non-elastic material, such as steel, aluminum and like metallic materials, but also composite materials or the like.

[0049] In an embodiment described herein, the first and/or second connecting element (such as a collar flange) may be split into multiple flat plates to reduce manufacturing costs. This could be achieved by either using one flat plate as one of the connecting elements and extending the other connecting element (as described in detail referring to FIG. 4), or using two flat plates and one circular ring to form an integral flange (as described in detail referring to FIG. 5).

[0050] FIG. 4 shows an embodiment of a flange connection. The flange connection 400 provides a first flange 410 and a second flange 420. Typically, the first flange 410 has a first portion 411 and a second portion 412. Also, the second flange 420 typically has a first portion 421 and a second portion 422. According to some embodiments, a first connecting element 430 and a second connecting element 440 are provided. In the embodiments of FIG. 4, the first connecting element 430 has the shape of a ring-like plate and the second connecting element 440 is provided as a collar flange having substantially an L-shape.

[0051] Typically, the first and second connecting element 430 and 440 are adapted to be connected to each other. In the example shown in FIG. 4, the first connecting element 430 is a plate extending in a substantially horizontal direction beyond the first portion 411 (such as the collar) of the first flange 410. The second connecting element 440 of the example shown in FIG. 4 substantially has an L-shape, which extends in a vertical direction along the first portions 411 and 421 of the first and second flanges 410 and 420. The extension of the second connecting element 440 of the flange connection 400 in the horizontal direction corresponds to the extension of the first connecting element 430. Typically, the extension of the second connecting element 440 in the horizontal

direction exceeds the extension of the first portion 421 of the second flange 420 in the horizontal direction.

[0052] FIG. 5 shows a flange connection 500 according to some embodiments described herein. Typically, the flange connection 500 provides a first flange 510 and a second flange 520. Each of the first and the second flanges 510, 520 may have a first portion 511, 521 and a second portion 512, 522, respectively. According to some embodiments, the flange connection 500 may have a first connecting element 530, a second connecting element 540 and a third connecting element 550. Typically, the three connecting elements 530, 540, and 550 are adapted to be connected to each other. According to embodiments described herein, the three connecting elements 530, 540, and 550 are adapted to connect the first portion 511 of the first flange 510 and the first portion 521 of the second flange 520. Typically, the first portions of the first and second flanges are formed as a collar extending in the horizontal direction.

[0053] Typically, two of the three connecting elements shown in FIG. 5 may be formed as a plate. In the example shown in FIG. 5, connecting elements 530 and 540 have a plate-like shape. Typically, the third connecting element 550 may have the shape of a ring extending around the circumference of the first and second flange, in particular around the collar of the flange.

[0054] According to some embodiments, the flanges of the flange connection may be connected at the second portion of the flanges too. As can exemplarily be seen in FIGS. 3 to 5, the second portions 312 and 322, 412 and 422 and 512 and 522 are connected by a fastening device, such as a screw, a bolt, or the like, in the examples of FIGS. 3 to 5, the fastening devices are shown as screws 360, 460 and 560, respectively.

[0055] Typically bolted joints may be used to connect the connecting elements (such as collar flanges) according to embodiments described herein, to provide the required clamping force for integrating the joint.

[0056] In another embodiment, the configuration can also be applied to an internal tower flange if additional space is required inside the tower shell, for instance in the case, where the down tower electrical system is assembled within the tower in pre-assembled power modules (PPM). According to some embodiments, which can be combined with other embodiments described herein, the second portion of the first and the second flange may be connected by connecting elements, the connecting elements being similar to those used for connecting the first portions of the flanges. Such an example is shown in FIG. 6. Typically, the flange connection 600 includes a first flange 610 and a second flange 620. According to some embodiments, the first flange 610 may have a first portion 611 and a second portion 612. Typically, the second flange 620 may also have a first portion 621 and a second portion 622.

[0057] In the embodiment shown in FIG. 6, the first portion 611 of the first flange 610 and the first portion 621 of the second flange 620 are connected by connecting elements 630 and 640. Typically, the connecting elements provide a ring-like shape or a segment of a ring-like shape and are adapted to be connected to each other (e.g., by fastening devices). Further, the connecting elements may be adapted to connect the first portions of the flanges with each other. Typically, the second portion 612 of the first flange 610 and the second portion 622 of the second flange 620 are connected by connecting elements 650 and 660. Typically, the connecting elements are adapted to be connected to each other by fastening

devices) and are adapted to connect the second portions of the flanges with each other. In the example of the flange connection of FIG. 6, the second portions 612 and 622 of the first and second flange 610 and 620 may have approximately the same extension in the horizontal direction as the first portions 611 and 621 of the first and second flanges. For instance, the second portion 612 or 622 may extend substantially in the horizontal direction from about 50 mm to about 200 mm, more typically from about 70 mm to about 150 mm, and even more typically from about 90 mm to about 110 mm. According to one embodiment, which can be combined with other embodiments described herein the extension of the second portion of the flange being provided as a collar in horizontal direction may be about 100 mm.

[0058] FIG. 7 shows an embodiment of a flange connection 740, wherein each of the first portions 741 and 751 of the first flange 743 and the second flange 744 are connected by a connecting element 770 formed in a one-piece design. Also the second portions 742 and 752 of the first flange 743 and the second flange 744 are connected by a connecting element 750 formed in a one-piece design. It is to be understood that the term “one-piece design” refers to a design of a connecting element, where the connecting element covers the height of the first portions of both the first and the second flanges. Typically, the connecting element 750 and 770 may be fastened by fastening devices 780 in a substantially horizontal direction.

[0059] According to some embodiments, the flange connection described herein may also be denoted as a bore-free flange connection or at least a partly bore-free flange connections. For instance, the first portion extending outwardly in the radial direction does not provide bores for fastening the flange, as can exemplarily be seen in FIGS. 3 to 5. In the examples shown in FIGS. 6 and 7, the first portion as well as the second portion of the flange may be described as being bore-free, being adapted for being connected by connecting elements.

[0060] FIG. 8 shows an example of a tower section 840 of a wind energy system. According to some embodiments, the tower section includes a flange, which provides a first portion 851 and a second portion 852. Typically, the first portion 851 and the second portion 852 extend in a substantially horizontal direction. Further, the tower section includes a connecting element 870 having substantially the shape of at least a segment of a ring, as will be explained in detail below. Typically, the connecting element 870 is placed on the first portion 851 of the flange and is adapted for securing the tower section 840. The connecting element may be fastened by fastening devices 860, which may be bolts, screws, or the like.

[0061] According to some embodiments, the connecting element 870 is divided in more than one part in circumferential direction, which is shown and explained in detail with respect to FIG. 11. Further, the tower section may include a second connecting element, which is placed on the second portion 852 of the flange and which is adapted for securing the tower section 840. According to some embodiments, the connecting element 870 may be adapted for securing the tower section 840 to another tower section of the wind energy system, a tower base ring, and a bearing at a tower top of the wind energy system, such as a yaw bearing at the top of the tower of the wind energy system.

[0062] Generally, the ratio between the extension of the first portion in the horizontal direction and the second portion in the horizontal direction may be about 1:1, 1:2, or up to 1:5.

For instance, the embodiments shown in FIGS. 6 and 7 show a ratio of the extension of the first portion to the extension of the second portion in horizontal direction of substantially 1:1. Other embodiments (such as embodiments shown in FIGS. 3 to 5) may provide a ratio of the extension of the first portion to the extension of the second portion in horizontal direction of exemplarily 1:2, 1:3, 1:4 or 1:5. According to further embodiments and dependent on the design of the flange, the ratio of the extension of the first portion to the extension of the second portion in horizontal direction of substantially may exceed the ration of 1:5.

[0063] In FIG. 9, a schematic cross-sectional view of an embodiment of a connecting element 700 (such as a collar flange) is shown, which can be combined with other embodiments described herein and can be used in every example of a flange connection described herein. The connecting element 700 of FIG. 9 is formed as a collar flange and substantially provides an L-like shape. The collar flange 700 may include a substantially vertical portion 710 and a substantially horizontal portion 720. Typically, the vertical portion 710 may include a contacting side 715 for contacting a vertical portion of a first or second portion of a flange. The horizontal portion 720 may include a contacting side 725 for contacting a horizontal portion of a first or second portion of a flange. According to sonic embodiments, the collar flange 700 is equipped with a slope to provide a dovetail shape for improving the clamping force between the first or second portion of a flange and the collar flange. The slope is indicated by angle 730 in FIG. 9. Typically, the angle 730 of FIG. 9 is measured from the horizontal direction.

[0064] In addition, also the collar of a flange, such as the first or second portion of a flange may be provided with a slope for improving the clamping force between the first or second portion of a flange and the connecting element. FIG. 10 shows a schematic cross-sectional view of an example of a flange having a first portion in a dovetail shape. The flange 800 of FIG. 10 includes a first portion 810 and a second portion 820 extending substantially in the horizontal direction. The first portion 810 provides a slope at the contacting face 815, at which a connecting element may contact the first portion 810. Typically, the slope is indicated by angle 830 in FIG. 10.

[0065] Typically, the angle provided on one or more components of the flange connection or flange assembly for forming the tapered shape or a slope may be between about 0.5° to about 7°, more typically between about 1° and 5°, and even more typically between about 2° and 4°. According to one embodiment, which can be combined with other embodiments described herein, the angle for forming the tapered shape may be about 2°.

[0066] According to some embodiments, both the flange and the connecting element may provide a slope in order to improve the clamping force between them. It may also be possible to provide the first and/or second portions of the flange with a slope. Typically, either component of a flange connection as described herein may be equipped with a slope on a contacting face for improving the clamping force. In particular, the embodiments described with respect to FIGS. 3 to 8 may provide a connecting element and/or a portion of the flange with a slope. It is also to be understood that components of the flange connection having a slope are also referred to as extending substantially in a horizontal direction, although the slope deviates from the horizontal direction.

[0067] According to some embodiments, which can be combined with other embodiments described herein, the connecting elements (such as the collar flange) can be split into multiple numbers of parts to make it as a split flange for easy connection and transportation. In that way, collar flanges can typically be transported in multiple parts and are within transportation limits. The collar flange can be assembled at the construction site of the wind turbine with minimum equipment.

[0068] For instance, FIG. 11 shows an embodiment of a connecting element 900 (such as a first or second connecting element described above) being provided including three segments 910, 920, and 930 of a ring-like shape. Each of the segments 910, 920, and 930 may enclose the same angle, as shown in FIG. 11. However, according to further embodiments, the angles of the segments may vary. Typically, the connecting element 900 is equipped with holes 940 adapted for accommodating fastening devices.

[0069] In FIG. 11, three segments are shown. However, it is to be understood that the number of segments is not limited. According to some embodiments, the connecting element includes only one part. According to further embodiments, the connecting element may include 3, 5, 10, or even more than 10 segments. According to yet further embodiments, the connecting element may include one segment for one fastening device.

[0070] Typically, assembled together the segments build a whole ring. According to other embodiments, the segments cover only a part of a 360° ring.

[0071] An example of an arrangement, wherein the connecting element covers only a part of the circumference of the wind energy tower, is shown in FIG. 12. FIG. 12 shows a cross-sectional view of an arrangement 1000 including a wind energy tower 1010 being equipped with a T-flange 1020. The T-flange may be equipped with holes 1025 or the like for accommodating fastening devices. The T-flange 1020 and the holes 1025 may be used to connect the flange to another flange.

[0072] Typically, the T-flange 1020 is only partly provided around the circumference of the tower 1010. For instance, the T-flange 1010 may have flattened portions 1030. The flattened portions 1030 may help complying with transportation or packaging limits. According to some embodiments, the flattened portions 1030 ensure that the arrangement 1000 does not exceed a shipping limit. The height 1040 of the arrangement 1000 is thus adapted to comply with shipping limits. However, in order to provide the required strength, although the T-flange covers only a part of the whole circumference of the tower 1010, connecting element 1050 and 1055 may be provided. Typically, the connecting elements 1050, 1055 may be connecting elements as described above and may be provided on a first portion 1060 of the T-flange, such as a collar 1060. The connecting elements 1050, 1055 are exemplarily shown with a curved shape at one side, however, it is to be understood that the shape of the connecting element may also be flat shaped without curvature.

[0073] The embodiment shown in FIG. 12 may also be denoted as a flange having lateral cut-outs for receiving the connecting elements. For instance, the flange may be adapted (e.g., by providing bores) for being fastened by fastening devices (such as screws, bolts, or the like) at a defined portion of the circumference and may be adapted for being fastened at other portions of the circumference (such as the cut-out portions) by connecting elements as described above.

[0074] According to some embodiments, the described flange assemblies may also be used to connect a wind energy tower to the ground. In this case, one flange and one connecting element may be used to fix the tower to respective components in the ground.

[0075] Typically, embodiments described herein refer to a method for connecting parts of a wind energy system. FIG. 13 shows a flow chart representing an example of such a method 1100. According to embodiments described herein, the wind energy system typically includes a first flange and a second flange. The first and the second flange each include a first portion and a second portion. The first portion may be a collar extending substantially in the horizontal direction. Typically, the first flange and the second flange may be flanges as described above with respect to FIGS. 3 to 8, 10, and 12.

[0076] According to some embodiments, in block 1110, a first connecting element is placed on the first portion of the first flange. Typically, the first connecting element has substantially the shape of at least a segment of a ring. In block 1120, a second connecting element is placed on the first portion of the second flange.

[0077] Typically the first connecting element and the second connecting element may have a ring-like shape or be a segment of a ring-like shape. Further, the first connecting element may be provided in several parts. For instance, in the case where the connecting element is provided as a segment of a ring-like shape, the connecting element may be described as including more than one segment.

[0078] Block 1130 refers to connecting the first connecting element and the second connecting element to connect the first portion of the first flange with the first portion of the second flange. Typically, fastening devices may be used to connect the first and second connecting element with each other.

[0079] The method according to embodiments described herein may be used for operating a wind energy system as described above. Also, the method may be used to connect parts of a wind energy system using the above described examples of flange connections and assemblies. For instance, the method for operating a wind energy system according to embodiments described herein may further include providing a third connecting element, which may help connecting the first and the second connecting elements.

[0080] Typically, the first and the second flanges may additionally be connected through the second portions of the flanges. For instance, fastening devices, such as screws, may be used to connect the second portion of the first flange with the second portion of the second flange.

[0081] According to some embodiments, the second portion of the first flange may be connected with the second portion of the second flange using further connecting elements, such as a third and fourth connecting element. Typically, the third and fourth connecting elements for connecting the second portion of the first flange with the second portion of the second flange may be of the same design as the first and second connecting elements. In particular, they may be designed as described above with respect to FIGS. 3 to 9 and 11 to 13.

[0082] Embodiments described herein are also applicable for a reverse taper tower door section keeping the collar within transportation limits.

[0083] The above-described systems and methods facilitate the transportation and assembly of wind turbine parts or components. More specifically, the flange connection according

to embodiments described above allows for complying with transportation limits, thereby decreasing costs for transportation and, at the same time, provides a reliable and exact connection of wind turbine parts, such as parts of a wind turbine tower.

[0084] Exemplary embodiments of systems and methods for a flange connection and a flange assembly are described above in detail. The systems and methods are not limited to the specific embodiments described herein, but rather components of the systems and/or steps of the methods may be utilized independently and separately from other components and/or steps described herein. For example, the flange connection described herein may be used in further applications, other than just those concerning connecting parts of a wind turbine, and are not limited to practice with only the wind turbine systems as described herein. Rather, the exemplary embodiment can be implemented and utilized in connection with many other rotor blade applications.

[0085] Although specific features of various embodiments of the invention may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the invention, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

[0086] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. While various specific embodiments have been disclosed in the foregoing, those skilled in the art will recognize that the spirit and scope of the claims allows for equally effective modifications. Especially, mutually non-exclusive features of the embodiments described above may be combined with each other. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A flange connection for two tower sections of a wind energy system, comprising:

- a) a first flange including a first portion and a second portion;
- b) a second flange including a first portion and a second portion; and,
- c) a first connecting element having substantially the shape of at least a segment of a ring and a second connecting element having substantially the shape of at least a segment of a ring, wherein the first connecting element and the second connecting element are adapted for being connected to each other and are adapted for connecting the first portion of the first flange with the first portion of the second flange.

2. The flange connection according to claim 1, wherein the first portion and the second portion of the first and the second flange extend in a substantially horizontal direction.

3. The flange connection according to claim 1, wherein the second portion of the first flange and the second portion of the second flange are adapted to be connected to each other.

4. The flange connection according to claim 1, further comprising a third connecting element adapted for connecting the first connecting element and the second connecting element.

5. The flange connection according to claim 1, wherein the first connecting element is adapted for being in contact with the first portion of the first flange and the second connecting element is adapted for being in contact with the first portion of the second flange in a mounted condition.

6. The flange connection according to claim 1, wherein at least one of the group consisting of the first portion of the first flange, the first portion of the second flange, the first connecting element and the second connecting element has a tapered shape.

7. The flange connection according to claim 1, wherein at least one of the first and the second connecting elements substantially have an L-shape.

8. The flange connection according to claim 1, wherein the second portion of the first flange and the second portion of the second flange are adapted to be connected to each other by a third connecting element having substantially the shape of at least a segment of a ring and a fourth connecting element having substantially the shape of at least a segment of a ring.

9. The flange connection according to claim 1, wherein at least one of the group consisting of the first connecting element and the second connecting element substantially has the shape of a plate.

10. The flange connection according to claim 1, wherein at least one of the first connecting element and the second connecting element is divided in more than one part in circumferential direction.

11. The flange connection of claim 1, wherein the flange connection is adapted to connect two parts of a wind energy tower to each other.

12. The flange connection according to claim 1, wherein the first connecting element and the second connecting element are substantially comprised of a substantially rigid material.

13. A wind energy system, comprising:

- a) a nacelle including a rotor;
- b) a tower carrying the nacelle;
- c) a flange on at least a part of the tower, wherein the flange includes a first portion and a second portion extending in a substantially horizontal direction; and,
- d) a connecting element having substantially the shape of at least a segment of a ring, wherein the connecting element is adapted for being placed on the first portion of the flange and is adapted for securing at least a part of the tower.

14. The wind energy system according to claim 13, wherein at least one of the group consisting of the first portion of the flange and the connecting element provides a tapered shape.

15. The wind energy system according to claim 13, wherein the connecting element is divided in more than one part in the circumferential direction.

16. A tower section of a wind energy system, comprising:

- a) a flange on at least a part of the tower section, wherein the flange includes a first portion and a second portion extending in a substantially horizontal direction; and,
- b) a connecting element having substantially the shape of at least a segment of a ring, wherein the connecting element is placed on the first portion of the flange and is adapted for securing the tower section.

17. The tower section according to claim **16**, wherein the connecting element is divided in more than one part in circumferential direction.

18. The tower section according to claim **16**, wherein at least one of the first portion of the flange and the connecting element provides a tapered shape.

19. The tower section according to claim **16**, further comprising a second connecting element adapted for being placed on the second portion of the flange and adapted for securing the tower section.

20. The tower section according to claim **16**, wherein the connecting element is adapted for securing the tower section to at least one of another tower section of the wind energy system, a tower base ring, and a bearing at a tower top of the wind energy system.

* * * * *