The invention relates to a tower section for assembling a wind turbine tower. The tower section comprises a flange at least at one end of the tower section. The flange is provided with holes for the connection elements. The flange have a first array of holes, where each hole is arranged in a first angle (α) relative to a longitudinal axis of the tower section, and a second array of holes, where each hole is arranged in a second angle (β) relative to the longitudinal axis. The first angle (α) is different from the second angle (β). The invention also relates to a foundation comprising a flange, where the flange of the foundation has characteristics corresponding to the characteristics of the tower section flange. The invention also relates to a wind turbine tower and to a wind turbine.
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TOWER SECTION FOR A WIND TURBINE TOWER

FIELD OF THE INVENTION

The present invention relates to a tower section for a wind turbine tower. The invention also relates to a foundation for a wind turbine tower and for a wind turbine. The invention furthermore relates to a wind turbine tower, to a wind turbine and to a method for assembling a wind turbine tower. Even further, the invention relates to use of connection elements for assembling a wind turbine tower.

BACKGROUND OF THE INVENTION

A wind turbine known in the art typically comprises a wind turbine tower positioned on a foundation and with a wind turbine nacelle positioned on top of the tower.

The wind turbine tower typically comprises a foundation and a number of annular tower sections mounted on top of each other, and where each tower section is made of a steel plate rolled into a circular or possibly polygonal shape and welded to constitute a circularly or polygonal closed tubular segment.

When the different sections, that constitute the wind turbine tower, have been transported to the site at which the tower is to be erected, the sections are connected by flanges. The flanges are provided with an array of through-going holes which allow a large number of bolts and corresponding nuts to connect a tower section with the foundation or with a neighbouring tower section.

A way to assemble sections of a wind turbine tower by using bolts and nuts is disclosed in international patent application WO 2007/059768 disclosing a wind turbine tower comprising a tower foundation and at least two tower sections connected by numerous sets of connecting means positioned in close proximity of each other. When the different sections that constitute the wind turbine tower have been transported to the site at which the tower is to be erected, the sections are connected by flanged joints. The flanges are provided with an array of
through-going holes which allow a large number of bolts and corresponding nuts to connect a tower section with the foundation or the next section. The connecting means comprises at least one nut and bolt with at least one assembly opening for interacting with an assembly tool.

JP 7026627 discloses a flange of an upper end of a large steel pipe and another flange having the same outer diameter with the one flange and said other flange being fixed to a lower end of a small steel pipe. Bolt holes slanting by 45 degrees against the axis of the pipes are formed on the superposed side of the upper and lower flanges, and bolts are screwed into the bolt holes to connect both steel pipes. The protruded part of the steel pipe joint is eliminated and hence, the appearance of the connected steel pipe column can be improved. Other bolts are not disclosed than bolts slanted by 45 degrees against the axis of the pipes.

The height of wind turbine towers has increased significantly in recent years, and therefore the strength requirements of the flanges have increased. Also, the strength and the number of bolts and corresponding nuts used in the flange joint connections have also increased significantly.

Hence, an improved construction and/or design of the flange, the flange connection and the tower segment for wind turbine towers would be advantageous, and a more efficient and/or reliable technique or method for assembling wind turbine towers would be advantageous.

SUMMARY OF THE INVENTION

One object of the present invention may be to provide design and/or construction and/or technique and/or assembling method allowing higher strength of the flange connection of wind turbine tower sections.

Another object of the invention may be to provide a tower section for a wind turbine tower that are less prone to damage resulting from the forces and stresses associated with the flange connection.
The term "bolt" should be understood as a headed fastener having an external thread that can engage an internal thread of a nut so that, after tightening, two sections of a wind turbine tower will be secured together, or that can engage with an internal thread made on the inner surface of a hole of sections of a wind turbine tower.

Yet another object of the invention may be to fit enough bolts with conventional externally polygonal heads, such as externally hexagonal heads, in a tower flange connection, and at the same time enabling tightening of the bolts with conventional tools without experiencing any problems, difficulties or inconveniences and without the need of having to use specially designed tools.

Even yet another object of the invention may be to fit enough bolts with internally polygonal heads, such as unbraco® or torx® internally polygonal heads, in a tower flange connection, and at the same time enabling tightening of the bolts with conventional tools without experiencing any problems, difficulties or inconveniences and without the need of having to use specially designed tools.

Furthermore, another object of the present invention can be to provide a wind turbine tower, a wind turbine and a method for assembling a wind turbine tower, and which solves the above-mentioned problems of the prior art.

Thus, the above described object and several other objects are obtained in a first aspect of the invention by providing a wind turbine tower section wherein the flange of the tower section is provided with holes for the connection elements, said holes having an orifice intended for facing a neighbouring flange of a neighbouring tower section, said flange of the tower section having a first array of holes, where each hole is arranged in a first angle relative to a longitudinal axis of the tower section, and a second array of holes, where each hole is arranged in a second angle relative to the longitudinal axis, and where the first angle is different from the second angle.

The present invention provides a tower section with a flange, which will give space for placing bolts, not only in a substantially vertical direction when the tower section is erected (i.e. substantially parallel with a longitudinal axis of the tower
section), but at least also at one angle relative to the longitudinal axis of the tower section. Thus, there will be enough space for more bolts or other similar connection elements in the flange. There may also be more space for bolt heads and for assembly tools for tightening the bolts, thus enabling tightening a bolt or a nut with standard tools, where such tools normally cannot be applied because of the connection elements being positioned too close along the flange.

The above described object and several other objects are obtained in an alternative or additional aspect of the invention by providing a wind turbine foundation comprising a flange for connecting the foundation, by means of connection elements such as bolts, to a bottom tower section of a wind turbine, wherein the flange is provided with holes for the connection elements, said flange having a first array of holes, where each hole is arranged in a first angle (α) relative to a longitudinal axis of the tower section, and a second array of holes, where each hole is arranged in a second angle (β) relative to the longitudinal axis, and where the first angle (α) is different from the second angle (β).

According to a possible aspect of the invention, the flange of the tower section and/or the foundation flange is also provided with a third array of holes, where each hole is arranged in a third angle relative to the longitudinal axis of the tower section, and where the third angle is different than the first angle and is different than the second angle.

This aspect of the invention provides a tower section and/or a foundation with a flange, which will give space for placing bolts, not only in a substantially vertical direction when the tower section is erected (i.e. substantially parallel with a longitudinal axis of the tower section), and/or when the foundation is established (i.e. substantially parallel with a longitudinal axis of the tower section), but also at more angles relative to the longitudinal axis of the tower section and/or the foundation.

Thus, there will be even more space for more bolts or other similar connection elements in the flange. There may also be even more space for bolt heads and for tools for tightening the bolts, thus enabling tightening a bolt or a nut with standard tools or even with machine-operated tools, where such tools normally
cannot be applied because of the connection elements being positioned to close along the flange.

In an aspect of the invention, the flange is directed inwards towards the inside of the tower section and/or the foundation and thus towards the inside of the wind turbine tower when erected. Directing the flange inwards towards the inside of the tower section and/or the foundation will provide need for tightening the connection elements from the inside of the tower section and/or the foundation, but may at the same time reduce the risk of mechanical or corrosion damage to the flanged joint. The flange directed inwards towards the inside will possible especially be provided at the bottom tower section intended for being joined with a corresponding foundation flange of a foundation for the wind turbine tower. Securing of the bottom tower section to the foundation is normally provided at a time of erection of the wind turbine tower and the wind turbine as such where access to the connection elements is readily available.

In another aspect of the invention, the flange is directed outwards from the outside of the tower section and/or the foundation and thus towards the exterior of the wind turbine tower when erected. Directing the flange outwards from the outside of the tower section and/or the foundation does not provide need for tightening the connection elements from inside the tower section or the foundation flange, but may at the same time increase the risk of mechanical or corrosion damage to the flanged joint. The flange directed outwards from the outside will possible especially be provided between two neighbouring tower sections. Mutual securing of two neighbouring tower sections, especially at the top of the wind turbine tower, is normally provided at a time of erection of the wind turbine tower and the wind turbine as such where access to the connection elements from inside the wind turbine tower may be limited, at least if using machine-operated tools for tightening the connection elements.

In another aspect of the invention, the flange projects radially relative to the longitudinal axis of the tower section and projects both inwards towards the interior of the tower section and/or the foundation and outwards from the exterior of the tower section. Increased securing of the flange may thus be obtained by adopting the present invention. Or, of only a first array of holes and a second
array of holes can be accommodated such as may the case at the foundation
where it is not possible to access the flange of the tower section from underneath
the flange.

In one aspect of the invention the second angle $\beta$ (beta) of the second array of
holes is between 15 degrees ($15^\circ$) and 75 degrees ($75^\circ$) relative to the
longitudinal axis of the tower section, preferably is between 30 degrees ($30^\circ$) and
60 degrees ($60^\circ$) relative to the longitudinal axis of the tower section, possibly
arranged approximately 45 degrees ($45^\circ$) relative to the longitudinal axis of the
tower section. An angle of 45 degrees is the angle leaving the most space for
connection elements when connection elements are provided both in a first array
of holes parallel with the longitudinal axis of the tower segment and at angles in a
second array of holes and a third array of holes. Leaving space for heads of the
connection elements may be especially advantageous for leaving space for tools
for tightening the connection elements by means of the heads.

In an aspect of the invention, bolt and nuts form the connection elements.
Tightening elements in the form of bolts and nuts are known as being
advantageous for connection two members such as flanges of two neighbouring
tower sections. However, the heads of the bolts and the nuts take up space
outside the holes which the bolts extend along. By the present invention, the
disadvantage of the heads of the bolts and the nuts taking up space is limited,
and in some applications of use, the disadvantage is even eliminated, because the
present invention leaves ample space for the bolts and nuts needed.

In another aspect of the invention the connection elements may comprise any one
or both of the following connection elements: bolted joint using bolts and
corresponding nuts and screw joint using bolts and threaded holes in one or both
of the sections to be connected. Pin bolts can also be used alone or combined in
any possible way with the above-mentioned joint connection types. The other
types of connection elements may possess advantages compared to bolts and nuts.
One advantage of other connection elements may be less space needed for heads
and nuts of the connection elements. Still other advantages of other connection
elements may be the possibility of using tools for tightening the connection
elements, which tools need less space for tightening the connection elements.

In one aspect of the invention, said tower sections and/or the foundation and a bottom tower section are connected in a flanged joint with more than two, e.g. three, arrays of holes for connection elements. More arrays of holes for connection elements may increase the total number connection elements possible for securing the flanged joints together, thus increasing the force possible for securing the connection. More arrays of holes for connection elements may also limit the size of e.g. head of bolts and nuts by limiting the size of e.g. bolts and nuts used, and compensating for the reduced force obtained by connection elements having a reduced size by increasing the number of connection elements. A reduced size of e.g. head of bolts and nuts may limit the size of tools for tightening the connection elements, which tools need less space for tightening the connection elements.

The assembly procedure of a set of connection elements such as a bolt and a corresponding nut requires at least one element being tightened e.g. one being tightened and one being held in place during tightening. A normal procedure may involve the nut being tightened and the bolt being held in place as the opposite procedure may result in an overturning of the bolt head.

By the present invention, it is possible to hold the bolt with a holding tool wherein a holding procedure does not require any significant work space. Consequently, the bolt may also have an internal assembly opening or a standard head such as hex head adapted to be held by a standard wrench while the nut is being tightened by an assembly tool. Also, by the present invention, possibly more space-requiring tools such as machine-operated tools for holding or tightening may be used. Consequently, more sets of connection elements in more favourable positions can be used in the flanged joint of a tower section and/or a foundation according to the invention, and thus establishing a higher strength of the joint or connection.

According to an aspect of the invention a method for assembling a wind turbine tower comprising at least two tower sections or segments at a wind turbine site, can be employed, wherein said method comprises the following steps:
- providing a bottom tower section and positioning another tower section along the bottom tower section and securing said other tower section to the bottom tower section by means of connection elements, wherein securing of the other tower section to the bottom tower sections is performed by inserting connection elements in a first array of holes in flanges of the bottom tower section and the other tower section, parallel to a longitudinal axis of the tower sections, and operating a tool for fastening the connection elements extending along the first array of holes, and by inserting connection elements in a second array of holes in flanges of the bottom tower section and the other tower section, at an angle relative to the longitudinal axis of the tower sections, and operating a tool for fastening the connection elements extending along the second array of holes.

According to another aspect of the invention a method for assembling a wind turbine tower comprising a foundation and at least one tower section, said method comprising the steps of:
- positioning a tower section on the foundation and preliminary or subsequently securing said bottom tower section to the foundation by means of connection elements, wherein securing of the tower section to the foundation is performed by inserting connection elements in a first array of holes in flanges of the foundation and the tower section, in a first angle, possibly parallel, relative to a longitudinal axis of the tower section, and operating an assembly tool for fastening the connection elements extending along the first array of holes, and by inserting connection elements in a second array of holes in flanges of the foundation and the tower section, at a second angle relative to the longitudinal axis of the tower section, and operating an assembly tool for fastening the connection elements extending along the second array of holes.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments according to the present invention will now be described in more detail with regard to the accompanying drawings or figures. The figures show one way of implementing the present invention and is not to be construed as being limiting to other possible embodiments falling within the scope of the attached set of claims.
Fig. 1 illustrates a wind turbine with a wind turbine tower constituted by a number of tower sections mutually joined by flanges, Fig. 2 is a cross-sectional view of flanges of a wind turbine tower section according to the present invention, and Fig. 3 is a plane view in a plane perpendicular to a longitudinal axis of a flange of a wind turbine tower section according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 illustrates a wind turbine 1 mounted on a foundation 6. The wind turbine comprises a tower 2 constituted by a number of tubular tower sections, and a wind turbine nacelle 3 positioned on top of the tower. The wind turbine rotor comprises three wind turbine blades 5 mounted on a hub 4. In the embodiment shown, the wind turbine tower is circular frusto-conical, but other shapes of the wind turbine tower may be envisaged, such as polygonal and such as cylindrical.

The different components of the wind turbine are usually transported separately to the site of mounting and assembled there, e.g. the different tower sections, the nacelle and the wind turbine blades. Assembly of the tower sections at the site of the wind turbine is performed by tools operated manually or by machinery.

Fig. 2 illustrates a cross-sectional view of a part of a top flange 11 and a bottom flange 12 between two wind turbine tower sections 13,14.

The tower section flanges 11,12 establishes a full circumference along the tower section around a longitudinal axis, but the flanges may also be divided into a number of flange segments together forming segments of a full circle. The figure illustrates a part of an upper cylindrical or conical tower section 13 which at a lower edge is provided with a flange 11 attached to the along a welding seam 15.

A lower cylindrical or conical tower section 14 is provided with a flange 10 along a welding seam 16. The design of the flange 12 is more or less a mirror image of the flange 11 of the upper tower section 13, said mirror image being viewed about a horizontal plane P.
The flanges 11,12 of the upper tower section 13 and the lower tower section 14 abut each other along the plane P extending substantially horizontally, perpendicular to a longitudinal axis A (see fig. 1) of the tower sections 13,14.

The flanges 11,12 each comprises a number of holes 17-22 arranged in three different arrays of holes. Each hole has an orifice extending to a surface of the flange, said surface intended for abutting a neighbouring flange of a neighbouring tower section, or said flange intended for abutting a flange of a tower foundation.

Relative to the flange 11 of the upper tower section 13, a first array of through-going holes 17 is arranged substantially parallel with the longitudinal axis A and substantially perpendicular to the horizontally extending plane P. Relative to the flange 12 of the lower tower section 14, a first array of through-going holes 18 is also arranged substantially parallel with the longitudinal axis A and substantially perpendicular to the horizontally extending plane P. Bolts 23 extend through the through-going holes 17,18. The bolts 23 hold the flanges 11,12 towards each other, together with other bolts 24,25, by means nuts 26 engaging a thread of the bolts 23. In alternative embodiments, the first array of holes may be arranged at an angle different from zero, i.e. different form parallel, relative to the longitudinal axis A of the tower sections. Angles different from zero may be angles between 345 degrees and 15 degrees, i.e. substantially parallel, but possibly with a slight inclination to the one side or the other side relative to the longitudinal axis A of the tower sections.

A second array of holes 19 in the flange 11 of the upper tower section 13 is arranged at a second angle \( \beta \) (beta) relative to the longitudinal axis A of the upper tower section 13 and the lower tower section 14. A third array of holes 20 is arranged at a third angle \( \gamma \) (gamma) relative to the longitudinal axis A of the upper tower section 13 and the lower tower section 14.

In the embodiment shown, the second angle \( \beta \) (beta) is 45 degrees. In other embodiments, the second angle \( \beta \) (beta) may be more or less than 45 degrees, more likely more than 45 degrees. If the second angle \( \beta \) (beta) is more than 45 degrees, possibly as large as 65 degrees, space requirement for the bolt head
and/or for the tightening tool may increase, but the force which the bolt may provide for securing the flanges towards each other will be higher than when the second angle $\beta$ (beta) is 45 degrees. Of the second angle $\beta$ (beta) is less than 45 degrees, possibly as small as 15 degrees, space requirement for the bolt head and/or for the tightening tool may decrease, but the force which the bolt may provide for securing the flanges towards each other will be lower than when the second angle $\beta$ (beta) is 45 degrees.

In the embodiment shown, the third angle $\gamma$ (gamma) is 135 degrees. In other embodiments, the third angle $\gamma$ (gamma) may be more or less than 135 degrees, more likely more than 135 degrees. If the third angle $\gamma$ (gamma) is more than 135 degrees, possibly as large as 165 degrees, space requirement for the bolt head and/or for the tightening tool may increase, but the force which the bolt may provide for securing the flanges towards each other will be higher than when the third angle $\gamma$ (gamma) is 135 degrees. Of the third angle $\gamma$ (gamma) is less than 135 degrees, possibly as small as 105 degrees, space requirement for the bolt head and/or for the tightening tool may decrease, but the force which the bolt may provide for securing the flanges towards each other will be lower than when the third angle $\gamma$ (gamma) is 135 degrees.

In the figure, the holes 17,18 and 19,20 and 21,22 are shown lying in the same plane of the paper. However, it is not the case of the physical implementation of the invention and in view of the technical effect to be obtained by the invention.

According to the physical implementation of the invention, the holes 17,18 will be lying in one angular position along the circumference of the tower section, the holes 19,20 will be lying in another angular position along the circumference of the tower section, and the holes 21,22 will be lying in yet another angular position along the circumference of the tower section. The angular position of the holes and the mutual angular displacement of the holes 17,18, the holes 19,20 and the holes 21,22, respectively, depend on different parameters such as the overall physical properties and structural strength of the flange, such as the tensile force which the bolts 23, 24, 25 are capable of establishing, and such as the dimensions of the bolts 23, 24, 25 in relation to the dimension of the flanges 11,12.
In the embodiment shown, the holes 19 of the second array in the upper tower section 13, and the holes 20 of the third array in the lower tower section 14 are through-going, while the holes 21 of the third array in the upper tower section 13 are not through-going, and the holes 22 of the second array in the lower tower section 14 are not through-going. These latter mentioned holes 21, 22 of the second array and of the third array have internal screw threads for receiving and engaging with a bolt 24, 25 having a corresponding screw thread. In possible other embodiments, either both or at least one of the holes 21, 22 of the second array and of the third array can be through-going holes allowing the flanges 11, 12 of the upper tower section 13 and of the lower tower section 14 to be joined as bolted joint with one or two bolt and a corresponding nut for each of the one or two bolts. In such embodiments, the corresponding nut will be provided at an inside of the tower sections.

The succession of the three arrays of holes 17-22 in the flanges 11, 12 should be chosen or predetermined in a suitable way in order increase the total number of bolts along the flanges 11, 12 and/or in order to ease the tightening operation. Any possible successions can be used. However, it is not very suitable to have, in the succession of the three arrays, holes of the same array next to each other, because in this way the tightening operation can be complicated or made more difficult.

Accordingly, the flange 11 of the upper tower section can have three arrays of holes 17, 19, 21 which are distributed along the circumference of the flange 11 in correspondence with the three arrays of holes 18, 20, 22 of the flange 12 of the lower tower section 14, and vice versa.

The flange connection may also be applied between a wind turbine foundation and a bottom tower section. The foundation flange will thus correspond to the flange 12 of the lower tower section 14, and the foundation flange will also be established according to the present invention. When the foundation flange connection is made according to the present invention, the foundation flange may however have a different design compared to the design of the flange 12 of the lower tower section 14 described above, but the angle array principle of the holes 17, 18, 19, 22 according to the present invention is to be maintained. The holes
21, 22 will however possibly not be provided, because bolts as the bolt 25 may be
difficult mounting and tightening, when the bottom flange is a foundation flange.

The flanges can be fixed to each other by at least two, e.g. three, arrays of
connection elements such as bolts penetrating partially or entirely through the
holes 17-22 in the flanges, hereby establishing the flanged joint between the two
wind turbine tower sections or between a wind turbine tower foundation and a
bottom wind turbine tower section.

Fig. 3 is a plane view in a plane perpendicular to a longitudinal axis of a tower
section. In the figure, the longitudinal axis is extending perpendicular to the plane
of the figure. The figure shows a first array of holes 17, a second array of holes 19
in the flange 11 of the tower section, and in dotted circles a third array of holes
20 (see also fig. 2) in a flange 12 of a neighbouring tower section. The figure also
shows the boundaries of the one section 27 of the flange 11 where the first array
of holes 19 is provided, and of the other section 28 of the flange 11 where the
second array of holes 19 is provided. The third array of holes 20 will be provided
in a corresponding other section of the flange of a neighbouring tower section.

In the figure shown, the number of holes of the first array, the second array and
the third array is limited in comparison with the actual number of holes of each
array of holes of a true flange of a tower section. However, the limited number of
holes is for the sake of clarity.

Also, in the embodiment shown, the sequence of holes, when viewed clock-wise,
is a hole of the first array, followed by a hole of the third array, subsequently
followed by a hole of the second array and subsequently followed by another hole
of the first array and so forth.

Alternative sequences may be provided such as a hole of the first array, followed
by a hole of the third array, subsequently followed by another hole of the first
array, subsequently followed by a hole of the second array and subsequently
followed by even another hole of the first array and so forth.
In even an alternative embodiment, the holes of the third array may be omitted, so that the sequence of holes is a hole of the first array followed by a hole of the second array, subsequently followed by another hole of the first array and subsequently followed by another hole of the first array, and so forth.

In the figures, the invention is described with reference to a tower sections. In alternative embodiments, the invention may be applied to a foundation for a wind turbine tower and for a wind turbine, said foundation having a flange.

Accordingly, an embodiment of the invention may relate to a foundation, wherein the flange also is provided with a third array of holes, where each hole is arranged in a third angle (β) relative to the longitudinal axis of the tower section, and where the third angle (β) is different than the first angle (α) and is different than the second angle (β).

An embodiment of the invention may also relate to a foundation, wherein the first angle (α) is between 345 degrees (345°) and 15 degrees (15°) relative to the longitudinal axis of the foundation, preferably is between 355 degrees (355°) and 5 degrees (5°) relative to the longitudinal axis of the foundation, more preferred is arranged 0 degrees (0°), i.e. parallel, relative to the longitudinal axis of the foundation.

An embodiment of the invention may also relate to a foundation, wherein the second angle (β) is between 15 degrees (15°) and 75 degrees (75°) relative to the longitudinal axis of the foundation, preferably is between 30 degrees (30°) and 60 degrees (60°) relative to the longitudinal axis of the foundation, possibly is arranged 45 degrees (45°) relative to the longitudinal axis of the foundation.

An embodiment of the invention may also relate to a foundation, wherein the holes of the second array of holes are through-going holes.

An embodiment of the invention may also relate to a foundation, wherein the holes of the second array of holes are threaded holes.
An embodiment of the invention may also relate to a foundation, wherein the third angle (Y) is between 105 degrees (105°) and 165 degrees (165°) relative to the longitudinal axis of the foundation, preferably is between 120 degrees (120°) and 60 degrees (150°) relative to the longitudinal axis of the foundation, possibly is arranged 135 degrees (135°) relative to the longitudinal axis of the foundation.

An embodiment of the invention may also relate to a foundation, wherein the holes of the third array of holes are through-going holes.

An embodiment of the invention may also relate to a foundation, wherein the holes of the third array of holes are threaded holes.

An embodiment of the invention may also relate to a foundation, wherein the sequence of the holes of the first array and the second array of holes is positioned along the flange circumferentially around the longitudinal axis of the foundation in such a way that the holes of the first array of holes is positioned at other angular positions along the flange than the holes of the second array of holes, when viewed in a plane perpendicular to the longitudinal axis of the foundation.

An embodiment of the invention may also relate to a foundation, wherein the sequence of the holes of the third array of holes is positioned along the flange circumferentially around the longitudinal axis of the foundation in such a way that the holes of the third array of holes is positioned at other angular positions along the flange than the holes of the first array of holes and at other angular positions along the flange than the holes of the second array of holes, when viewed in a plane perpendicular to the longitudinal axis of the foundation.

An embodiment of the invention may also relate to a foundation, said foundation capable of accommodating connection elements, and where

- assembly means, such as heads of bolts or nuts for bolts, of the connection elements are intended for being operated by an assembly tool when the connection elements are in position in the holes of the first array and the second array of holes, and where
  - the holes of the first array and the second array of holes are mutually placed along the flange so that the assembly means, when the connection elements are
in position in the holes of the first array of holes and the second array of holes, exhibit an extension along the flange
- said extension of the assembly means along the flange allowing the assembly tool to interact with the assembly means of neighbouring connection elements only when the first angle (α) is different from the second angle (β).

An embodiment of the invention may also relate to a foundation, said foundation capable of accommodating connection elements, and where
- assembly means, such as heads of bolts or nuts for bolts, of the connection elements are intended for being operated by an assembly tool when the connection elements are in position in the holes of the first array, the second array and the third array of holes, and where
- the holes of the first array, the second array and the third array of holes are mutually placed along the flange so that the assembly means, when the connection elements are in position in the holes of the first array, the second array and the third array of holes, exhibit an extension along the flange
- said extension of the assembly means along the flange allowing the assembly tool to interact with the assembly means of neighbouring connection elements only when the third angle (γ) is different from the first angle (α) and is different from the second angle (β).

An embodiment of the invention may also relate to a foundation, where the sequence of holes is a hole of the first array, followed by a hole of the third array, subsequently followed by a hole of the second array and subsequently followed by another hole of the first array and so forth.

An embodiment of the invention may also relate to a foundation, where the sequence of holes is a hole of the first array, followed by a hole of the third array, subsequently followed by another hole of the first array, subsequently followed by a hole of the second array and subsequently followed by even another hole of the first array and so forth.

An embodiment of the invention may also relate to a foundation, where the sequence of holes is a hole of the first array followed by a hole of the second
array, subsequently followed by another hole of the first array and subsequently followed by another hole of the first array, and so forth.

An embodiment of the invention may also relate to a foundation, wherein the flange projects radially relative to the longitudinal axis of the foundation and extends inwards towards the interior of the foundation.

An embodiment of the invention may also relate to a foundation, wherein the flange projects radially relative to the longitudinal axis of the foundation and extends outwards from the exterior of the foundation.

An embodiment of the invention may also relate to a foundation, wherein the flange projects radially relative to the longitudinal axis of the foundation and extends both inwards towards the interior of the foundation and outwards from the exterior of the foundation.

Although the present invention has been described in connection with the specified embodiments, it should not be construed as being in any way limited to the presented examples. The scope of the present invention is to be interpreted in the light of the accompanying claim set. In the context of the claims, the terms "comprising" or "comprises" do not exclude other possible elements or steps. Also, the mentioning of references such as "a" or "an" etc. should not be construed as excluding a plurality. Furthermore, individual features mentioned in different claims, may possibly be advantageously combined, and the mentioning of these features in different claims does not exclude that a combination of features is not possible and advantageous.
CLAIMS

1. A tower section for assembling a wind turbine tower, said tower section comprising
- a flange at least at one end of the tower section for connecting the tower section, by means of connection elements such as bolts, to a neighbouring flange of a neighbouring tower section or of a tower foundation, wherein
- the flange is provided with holes for the connection elements, said holes having an orifice intended for facing the neighbouring flange of the neighbouring tower section or of the tower foundation, and said flange of the tower section having
  - a first array of holes, where each hole is arranged in a first angle (α) relative to a longitudinal axis of the tower section, and
  - a second array of holes, where each hole is arranged in a second angle (β) relative to the longitudinal axis, and
- where the first angle (α) is different from the second angle (β).

2. A tower section according to claim 1, wherein the flange also is provided with a third array of holes, where each hole is arranged in a third angle (γ) relative to the longitudinal axis of the tower section, and where the third angle (γ) is different than the first angle (α) and is different than the second angle (β).

3. A tower section according to claim 1, wherein the first angle (α) is between 345 degrees (345°) and 15 degrees (15°) relative to the longitudinal axis of the tower section, preferably is between 355 degrees (355°) and 5 degrees (5°) relative to the longitudinal axis of the tower section, more preferred is arranged 0 degrees (0°), i.e. parallel, relative to the longitudinal axis of the tower section.

4. A tower section according to claim 1, wherein the second angle (β) is between 15 degrees (15°) and 75 degrees (75°) relative to the longitudinal axis of the tower section, preferably is between 30 degrees (30°) and 60 degrees (60°) relative to the longitudinal axis of the tower section, possibly is arranged 45 degrees (45°) relative to the longitudinal axis of the tower section.

5. A tower section according to claim 1 or claim 4, wherein the holes of the second array of holes are through-going holes.
6. A tower section according to claim 1 or claim 4, wherein the holes of the second array of holes are threaded holes.

5 7. A tower section according to claim 2, wherein the third angle (Y) is between 105 degrees (105°) and 165 degrees (165°) relative to the longitudinal axis of the tower section, preferably is between 120 degrees (120°) and 60 degrees (150°) relative to the longitudinal axis of the tower section, possibly is arranged 135 degrees (135°) relative to the longitudinal axis of the tower section.

10 8. A tower section according to claim 2 or claim 7, wherein the holes of the third array of holes are through-going holes.

9. A tower section according to claim 2 or claim 7, wherein the holes of the third array of holes are threaded holes.

10. A tower section according to any one of claims 1 or claims 3-6, wherein the sequence of the holes of the first array and the second array of holes is positioned along the flange circumferentially around the longitudinal axis of the tower section in such a way that the holes of the first array of holes is positioned at other angular positions along the flange than the holes of the second array of holes, when viewed in a plane perpendicular to the longitudinal axis of the tower section.

11. A tower section according to any one of claim 2 or claims 7-9, wherein the sequence of the holes of the third array of holes is positioned along the flange circumferentially around the longitudinal axis of the tower section in such a way that the holes of the third array of holes is positioned at other angular positions along the flange than the holes of the first array of holes and at other angular positions along the flange than the holes of the second array of holes, when viewed in a plane perpendicular to the longitudinal axis of the tower section.

12. A tower section according to any one of claims 1 or claims 3-6 or claim 10, said tower section capable of accommodating connection elements, and where assembly means, such as heads of bolts or nuts for bolts, of the connection elements are intended for being operated by an assembly tool when the
connection elements are in position in the holes of the first array and the second array of holes, and where
- the holes of the first array and the second array of holes are mutually placed along the flange so that the assembly means, when the connection elements are in position in the holes of the first array of holes and the second array of holes, exhibit an extension along the flange
- said extension of the assembly means along the flange allowing the assembly tool to interact with the assembly means of neighbouring connection elements only when the first angle (α) is different from the second angle (β).

13. A tower section according to any one of claims 2 or claims 7-9 or claim 11, said tower section capable of accommodating connection elements, and where
- assembly means, such as heads of bolts or nuts for bolts, of the connection elements are intended for being operated by an assembly tool when the connection elements are in position in the holes of the first array, the second array and the third array of holes, and where
- the holes of the first array, the second array and the third array of holes are mutually placed along the flange so that the assembly means, when the connection elements are in position in the holes of the first array, the second array and the third array of holes, exhibit an extension along the flange
- said extension of the assembly means along the flange allowing the assembly tool to interact with the assembly means of neighbouring connection elements only when the third angle (γ) is different from the first angle (α) and is different from the second angle (β).

14. A tower section according to any one of claims 2 or claims 7-9 or claim 11 or claim 13, where the sequence of holes is a hole of the first array, followed by a hole of the third array, subsequently followed by a hole of the second array and subsequently followed by another hole of the first array and so forth.

15. A tower section according to any one of claims 2 or claims 7-9 or claim 11 or claim 13, where the sequence of holes is a hole of the first array, followed by a hole of the third array, subsequently followed by another hole of the first array, subsequently followed by a hole of the second array and subsequently followed by even another hole of the first array and so forth.
16. A tower section according to any one of claims 1 or claims 3-6 or claim 10 or claim 12, where the sequence of holes is a hole of the first array followed by a hole of the second array, subsequently followed by another hole of the first array and subsequently followed by another hole of the first array, and so forth.

17. A tower section according to any one of claims 1-16, wherein the flange projects radially relative to the longitudinal axis of the tower section and extends inwards towards the interior of the tower section.

18. A tower section according to any one of claims 1-16, wherein the flange projects radially relative to the longitudinal axis of the tower section and extends outwards from the exterior of the tower section.

19. A tower section according to any one of claims 1-16, wherein the flange projects radially relative to the longitudinal axis of the tower section and extends both inwards towards the interior of the tower section and outwards from the exterior of the tower section.

20. A wind turbine tower comprising at least two tower sections according to any of claims 1-19.

21. A wind turbine tower comprising at least a tower section according to any of claims 1-19, said tower section being a bottom tower section, and said wind turbine tower also comprising a foundation, and where said bottom tower section is attached to the foundation.

22. A wind turbine tower according to claim 20 or claim 21, where the first array of holes both of the one tower section and of the other tower section are through-going holes adapted for connection elements consisting in threaded bolts and nuts, and where the second array of holes are through-going holes in the one tower section and are threaded holes in the other tower section, respectively, said second array of holes adapted for connection elements consisting in threaded bolts only intended for engagement with the threaded holes of the tower sections.
23. A wind turbine tower according to claim 22, where the third array of holes are through-going holes in the one tower section and are threaded holes in the other tower section, respectively, said third array of holes adapted for connection elements consisting in threaded bolts only intended for engagement with the threaded holes of the tower sections.

24. A foundation for assembling a wind turbine, said foundation comprising a flange for connecting the foundation, by means of connection elements such as bolts, to a bottom tower section of a wind turbine, wherein the flange is provided with holes for the connection elements, said flange having a first array of holes, where each hole is arranged in a first angle (α) relative to a longitudinal axis of the tower section, and a second array of holes, where each hole is arranged in a second angle (β) relative to the longitudinal axis, and where the first angle (α) is different from the second angle (β).

25. A wind turbine comprising a tower with at least two tower sections according to any of claims 1-19.

26. A wind turbine comprising a tower section according to any of claims 1-19, said tower section being a bottom tower section, and said wind turbine also comprising a foundation, and where said bottom tower section is attached to the foundation.

27. A wind turbine according to claim 25 or claim 26, where the first array of holes both of the one tower section and of the other tower section are through-going holes adapted for connection elements consisting in threaded bolts and nuts, and where the second array of holes are through-going holes in the one tower section and are threaded holes in the other tower section, respectively, said second array of holes adapted for connection elements consisting in threaded bolts only intended for engagement with the threaded holes of the tower sections.

28. A wind turbine according to claim 27, where the third array of holes are through-going holes in the one tower section and are threaded holes in the other tower section, respectively, said third array of holes adapted for connection
elements consisting in threaded bolts only intended for engagement with the threaded holes of the tower sections.

29. Method for assembling a wind turbine tower at a wind turbine site, said wind turbine comprising at least one tower section, said method comprising the steps of:
   - providing a bottom tower section and positioning another tower section along the bottom tower section and securing said other tower section to the bottom tower section by means of connection elements, wherein securing of the other tower section to the bottom tower sections is performed
   - by inserting connection elements in a first array of holes in flanges of the bottom tower section and the other tower section, in a first angle, possibly parallel, relative to a longitudinal axis of the tower sections, said holes of the bottom tower section having an orifice intended for facing a flange of the other tower section, and operating an assembly tool for fastening the connection elements extending along the first array of holes, and
   - by inserting connection elements in a second array of holes in flanges of the bottom tower section and the other tower section, at a second angle relative to the longitudinal axis of the tower sections, and operating an assembly tool for fastening the connection elements extending along the second array of holes.

30. Method for assembling a wind turbine tower at a wind turbine site, said wind turbine comprising a foundation and at least one tower section, said method comprising the steps of:
   - positioning a tower section on the foundation and preliminary or subsequently securing said bottom tower section to the foundation by means of connection elements, wherein securing of the tower section to the foundation is performed
   - by inserting connection elements in a first array of holes in flanges of the foundation and the tower section, in a first angle, possibly parallel, relative to a longitudinal axis of the tower section, said holes of the tower section having an orifice intended for facing a flange of the tower foundation, and operating an assembly tool for fastening the connection elements extending along the first array of holes, and
   - by inserting connection elements in a second array of holes in flanges of the
foundation and the tower section, at a second angle relative to the longitudinal axis of the tower section, and operating an assembly tool for fastening the connection elements extending along the second array of holes.

31. Method according to claim 29 or claim 30, said method furthermore comprising the step of inserting connection elements in a third array of holes in flanges of the bottom tower section and the other tower section, at a third angle relative to the longitudinal axis of the tower sections, and operating an assembly tool for fastening the connection elements extending along the third array of holes.

32. Use of connection elements extending through a first array and a second array of holes of a wind turbine tower flange for assembling a wind turbine tower section to a neighbouring wind turbine tower section or to a wind turbine tower foundation at a wind turbine site, said first array of holes being arranged in a first angle (α) relative to a longitudinal axis of the tower section, and said second array of holes being arranged in a second angle (β) relative to the longitudinal axis, and where the first angle (α) is different from the second angle (β).

33. Use according to claim 32, said use comprising connection elements extending through a third array of holes being arranged in a third angle (γ) relative to the longitudinal axis of the tower section, and where the third angle (γ) is different than the first angle (α) and is different than the second angle (β).

34. Use according to claim 32 or claim 33, said use comprising connection elements extending at an angle (α) between 345 degrees (345°) and 15 degrees (15°) relative to the longitudinal axis of the tower section, preferably between 355 degrees (355°) and 5 degrees (5°) relative to the longitudinal axis of the tower section, more preferred at 0 degrees (0°), i.e. parallel, relative to the longitudinal axis of the tower section.
Fig. 3