

Floating assembly for generating solar power and method for installing it

5 The invention firstly relates to a floating assembly for generating solar power, comprising at least one floating element which in an operational position floats on a water surface, with one or more solar panels resting on top of each element and with mooring lines extending between each element and a fixed mooring arrangement.

10 The element (which can be a rigid element or a flexible element and which for obtaining a required buoyancy may be gas-filled, for example using nitrogen or air) should be moored to the fixed mooring arrangement in such a manner that its optimal position (with respect to the generation of
15 power by the solar panels) is maintained as much as possible under varying conditions (waves, current, tidal movements etc.), while still being able to conform to, for example, waves.

 It is noted that within the context of the present
20 invention the expression "fixed mooring arrangement" merely intends to indicate a mooring arrangement which in general has a substantially fixed geographical location, but which however in certain instances could be capable of limited movements (such as oscillations) around that fixed location.

25 In view of the above it is an object of the present invention to provide an improved floating assembly for generating solar power.

 In accordance with the present invention the fixed
30 mooring arrangement comprises at least one assembly of two buoys which are intended to be anchored by means of anchor lines, wherein at least one string line is provided extending directly or indirectly between the two buoys, wherein the at least one string line is located below the water surface and wherein at least some of the mooring lines of each

element extend between said element and the at least one string line.

Such an arrangement yields good results in that the position of the flexible elements can be maintained as desired under changing conditions (such as waves, current and tidal movements) with relatively low mooring forces compared to a more rigid mooring system. The position where the mooring lines engage the element, may vary widely and, among others, may depend on the shape and/or outline of the element.

It is noted that the power generated by the solar panels may be transferred to the buoys which then may act as a landing point for a power cable towards an external location. Such a power cable also may be combined with the anchor cable.

In one embodiment the mooring arrangement comprises at least one assembly of four buoys, which buoys substantially are arranged in a rectangular pattern defining longitudinal sides and transverse sides, wherein two buoy connection lines are provided which each substantially connect two buoys located at a same transverse side of the rectangular pattern and which are located below the water surface, and wherein the at least one string line extends between the two buoy connection lines or, directly or indirectly, between two buoys, substantially in parallel to the longitudinal sides.

As stated, the buoy connection lines substantially connect two buoys located at a same transverse side of the rectangular pattern. The use of 'substantially' tries to express that such a connection can occur directly when the buoy connection lines are attached directly to the buoys, but also may occur indirectly when the buoy connection lines are attached to a section of the anchor lines just below the

buoys. This applies likewise for the string line(s) if connected (directly or indirectly) to the buoys. If more than one string line is applied, the manner of connection can vary among the string lines, whereas further the connection
5 manner can differ for two opposite ends of a same string line. Depending on which situation applies, the vertical dimensions of the buoys may vary.

In one embodiment at least some of the mooring lines may extend between the element and the buoy connection
10 lines. This offers additional stability.

In one embodiment at least two parallel string lines are provided, and at least some of the mooring lines of each element extend between said element and the two string lines. In such an embodiment, therefore, each element
15 uses two string lines for (at least part) of its mooring.

Preferably, then, the element has two opposite longitudinal edges extending in parallel with the string lines, wherein a first group of mooring lines extends between one longitudinal edge and a first one of the string
20 lines, whereas a second group of mooring lines extends between the other longitudinal edge and a second one of the string lines. This yields a very stable mooring of the elements. Of course, in such an embodiment the elements also may have other mooring lines (for example at transversal
25 edges) extending to, for example, a buoy connection line.

For further stabilizing the position of the elements the mooring lines may diverge. Thus, a width of a element as measured between opposite longitudinal edges of the element may be smaller than a distance between the two parallel string lines, such that the mooring lines belonging to
30 the first group diverge in a downward direction relative to the mooring lines belonging to the second group, or said

width may be larger than said distance, such that the mooring lines belonging to the first group converge in said downward direction relative to the mooring lines belonging to the second group.

5 In one embodiment multiple pairs of two adjacent parallel string lines each are provided, wherein a plurality of successive elements are provided which are arranged in parallel longitudinal rows, wherein the elements of a same row with their mooring lines are connected to the string
10 lines of a same pair. Although adjacent pairs of string lines could share common string lines (such that for example, three string lines define two pairs), it is preferred that the pairs are completely separated. As a result, free passages between the rows of elements are defined which can
15 be navigated, for example by a vessel for service or installing purposes. Further, such free passages allow the access of sunlight into the sea, resulting in a minimisation of the environmental impact.

 For a further stabilisation, adjacent string
20 lines, and preferably string lines belonging to a same pair, may be interconnected by auxiliary lines which preferably each are provided between successive elements. A position below the elements, however, is conceivable too. Some of the mooring lines may be connected to such auxiliary lines.

25 In one embodiment at least three parallel string lines are provided, wherein a plurality of elements are provided which, as considered in a longitudinal direction, are arranged in such a staggered pattern that the elements with their two groups of mooring lines alternately are con-
30 nected to a first and second one, respectively, of the string lines and a second and third one, respectively, of the succession of string lines. As a result, the coherence

between the string lines and, thus, in the entire mooring arrangement may be improved.

It is conceivable that all mooring lines of an element extend between said element and a single string line.

5 For example, when at least part of the mooring lines are grouped in two groups at opposite longitudinal edges of the element, the mooring lines of both groups converge towards the single string line. This simplifies the structure of the mooring assembly and yields a symmetrical mooring.

10 Preferably, in the said operational position, each buoy connection line and string line extends substantially at a level between 0,5 and 20 meters, and preferably between 1,5 and 2,5 meters below the water surface, among others depending on the local circumstances (such as waves, current,
15 water depth, influence of wind) and dimensions of the elements of the floating assembly.

Further it is conceivable that the buoy connection lines and/or string line(s) at a position between the buoys are provided with auxiliary buoys, such as to further stabilise the position (especially vertical level in the water
20 column) of the mooring arrangement. Such auxiliary buoys also may be provided at the interconnection between buoy connection lines and string lines or at the auxiliary lines, if provided. The auxiliary buoys may provide additional
25 buoyancy, especially in the case of buoy connection lines, string lines and/or auxiliary lines which are heavier than water.

The floating assembly may comprise multiple assemblies each with four buoys. For example, with a matrix of
30 3x3 buoys four assemblies with each four buoys may be defined located adjacent each other in a square pattern (in which buoys (and possibly buoy connection lines and/or string lines) may belong to different assemblies). This,

however, does not preclude the possibility to arrange the buoys in a different pattern. Basically, the mooring arrangement (and thus the floating assembly and its capacity to generate solar power) in such a manner may be extended
5 infinitely, as desired.

The buoys (and auxiliary buoys, if provided) may at least partially extend above the water surface, or the buoys may be fully submerged.

In one embodiment the anchor lines extend between
10 the buoys and fixed anchor points, such as gravity-based anchors, piles, suction anchors and drag anchors (for example resting on the seabed). However, other fixed points of attachment (for example located on the seabed) or other structures which are capable of providing a geographically fixed
15 mooring location, can be used as well.

Most commonly, the buoy connection lines (in a natural manner) will extend in a curved manner (substantially in a horizontal plane), such that string lines extending between the buoy connection lines at positions close
20 to the buoys should be longer than string lines extending between the buoy connection lines at positions further away from the buoys.

The invention secondly relates to method for installing a floating assembly according to any of the previous claims, comprising at least the steps of providing a
25 vessel having mounted thereon a drum on which an assembly is wound comprising at least string lines with elements in a deflated state attached to the string lines; positioning and anchoring a first pair of buoys using the anchor lines; attaching a first one of the buoy connection lines to the
30 first pair of buoys; attaching one end of the string lines to said first buoy connection line; gradually unwinding the assembly from the drum; inflating the elements after being

unwound from the drum, and connecting the other end of the string lines, after being unwound from the drum, to a second buoy connection line which has been attached to a second pair of buoys which previously has been positioned and anchored using the anchor lines.

With such a method a vessel may be used for quickly installing a floating assembly in a (nearly) automated manner. The second pair of buoys also may be used as the first pair for a consecutive floating assembly and so on.

The method may be varied. For example, the buoy connection lines also may be provided on the drum, connected to the string lines.

Hereinafter the invention will be elucidated while referring to the drawings, in which:

Figure 1, in a schematic perspective manner, illustrates a first embodiment of a floating assembly in accordance with the present invention;

Figure 2 in part and schematically shows a top plan view of an embodiment;

Figure 3 in part and schematically shows a top plan view of another embodiment;

Figure 4 in part and schematically shows a top plan view of yet another embodiment, and

Figure 5 in a frontal view and schematically shows an embodiment with a single string line for an element.

Firstly, referring to figure 1, an embodiment of a floating assembly for generating solar power in accordance with the present invention is illustrated in a perspective and highly schematic manner. The floating assembly comprises at least one floating flexible element 1 filled with air (or another gas, for example nitrogen) which in an operational

position floats on a water surface 2. One or more solar panels 3 rest on top of each flexible element. Mooring lines 4 are provided which extend between the flexible element 1 and a fixed mooring arrangement which will be described below.

5 Whereas this figure illustrates mooring lines 4 attached to opposite longitudinal edges of the element 1, also mooring lines 4' could be provided attached to other parts of the element, such as transversal edges.

The mooring arrangement comprises at least one assembly of four buoys 5 and 5' which are intended to be anchored by means of anchor lines 6 which, for example, are attached to gravity-based anchors (or weights) 7 resting on the seabed 8. The buoys 5,5' substantially are arranged in a rectangular pattern defining longitudinal sides (defined by two buoys 5 and two buoys 5', respectively) and transverse sides (defined each by a combination of a buoy 5 and a buoy 5').

As part of the mooring arrangement two buoy connection lines 9 are provided which (in the illustrated embodiment) each connect two buoys 5 and 5' located at a same transverse side of the rectangular pattern. As an alternative, these buoy connection lines 9 also could be attached to a part of the anchor lines 6 just below the respective buoys.

Further, this embodiment features two string lines 10 that extend between the two buoy connection lines 9 substantially in parallel to the above-mentioned longitudinal sides. The dimensioning and positioning of the buoys 5,5' is such that the buoy connection lines 9 and the string lines 10 are located below the water surface 2 (for example at a depth of between 1,5 and 2,5 meters).

The string lines 10 also may be attached to the buoys 5,5' or to the anchor lines 6 just below the buoys.

In a very basic embodiment (not illustrated) only two buoys are provided connected by a single buoy connection line which than also acts as a string line.

5 The mooring lines 4 of the flexible element 1 extend (in most cases substantially vertically) between said flexible element 1 and the string lines 10. Specifically, in the illustrated embodiment the flexible element 1 has two opposite longitudinal edges (not numbered) extending in parallel with the string lines 10, wherein a first group of
10 mooring lines 4 extends between one of the longitudinal edges and a first one of the string lines 10, whereas a second group of mooring lines 4 extends between the other longitudinal edge and a second one of the string lines 10.

There may be more mooring lines, for example as
15 indicated with 4' in figure 1, which extend to the buoy connection lines 9 (or to an auxiliary line 11 to be described below and as shown in figure 2).

Further figure 1 illustrates that a width W of the flexible element 1 as measured between its opposite longitudinal edges is smaller than a distance D between the two
20 parallel string lines 10, such that the mooring lines 4 belonging to the first group diverge in a downward direction relative to the mooring lines 4 belonging to the second group (although these mooring lines extend substantially
25 vertically). As an alternative (not illustrated) said width W could be larger than said distance D, such that the mooring lines 4 belonging to the first group would converge in said downward direction relative to the mooring lines 4 belonging to the second group.

30 Whereas in figure 1 part of the buoys 5, 5' emerges above the water surface 2, in another embodiment (not illustrated) the buoys could be totally submerged.

In figure 2 part of an embodiment of a floating assembly has been illustrated in a schematic top plan view. The anchor lines have been omitted in this view (as applies too for figures 3 and 4). The assembly comprises two pairs
5 10' and 10" of two parallel string lines each. A plurality of successive flexible elements 1 are provided which are arranged in parallel longitudinal rows, wherein the flexible elements 1 of a same row with their mooring lines 4 are connected to the string lines of a same pair 10' or 10". The
10 number of pairs and number of flexible elements may differ as desired.

In such a configuration one (or more) passages P are defined between adjacent pairs of string lines (and respective flexible elements) which, because the buoy connection lines 9 extend at a level below the water surface, may
15 be navigated by a vessel and which offer a passage for sunlight.

Figure 2 further shows that adjacent string lines, and preferably string lines belonging to a same pair 10' or
20 10", may be interconnected by auxiliary (stabilising) lines 11 (shown in dotted lines) which preferably each are provided between successive flexible elements 1 (but also could be provided at another location, such as underneath a flexible element 1, as allowed by the level of the string lines
25 below the water surface and, as a result, generally below the lowest part of the flexible element which commonly has a low weight and thus a very limited draught). Another possible location is indicated by 11'.

Figure 2 also shows the possibility of mooring
30 lines 4' extending between transversal edges of the flexible elements 1 and the auxiliary lines 11 and/or the buoy connection lines 9.

It is noted that such auxiliary lines generally also could be wound on the drum during the method for installing the floating assembly, as discussed herein.

Figure 3 shows an example of an embodiment in which multiple string lines 10 are provided as well as a plurality of flexible elements 1 which, as considered in a longitudinal direction, are arranged in such a staggered pattern that the flexible elements 1 with their two groups of mooring lines alternately are connected to a first and second one, respectively, of the string lines and a second and third one, respectively, of the succession of string lines and so on.

Figure 3 also illustrates the use of auxiliary buoys 12. Generally, such auxiliary buoys 12 may be provided at the buoy connection lines 9 and/or string line(s) 11 (as illustrated) at a position between the buoys 5, or at an interconnection there between.

Whereas in the previously illustrated embodiments each flexible element 1 with its mooring lines 4 is attached to two string lines 10, it also is conceivable that all mooring lines 4 of a flexible element are attached to a single string line (see figure 5 which is a very schematic frontal view).

From the figures 1-3 it appears that the buoy connection lines 9 extend in a curved manner (in a horizontal plane), such that string lines 10 extending between the buoy connection lines 9 at positions close to the buoys 5, 5' should be longer than string lines 10 extending between the buoy connection lines at positions further away from the buoys. Such a curved shape occurs in a natural manner as a result from the forces (especially tension forces arising from the string lines) acting on the buoy connection lines.

Whereas in the embodiments illustrated and described above there are four buoys which define a single assembly of buoys, the floating assembly also may comprise a larger number of buoys which are positioned in such a pattern that multiple assemblies each with four buoys will be defined. As an example, figure 4 shows nine buoys 5 arranged according to a 3x3 matrix, defining four assemblies (top left, top right, bottom left and bottom right in the figure). In such an arrangement some of the buoys are part of two or even four assemblies (as applies to the central buoy). This may apply too for some buoy connection lines (as illustrated schematically by 9') to which, then, the string lines of two adjacent assemblies would be connected.

The floating assembly may be installed in different ways. One possible method (or process) of installing it comprises at least the steps as described below.

A vessel is provided which has mounted thereon a rotatable drum on which an assembly is wound comprising at least the pre-installed buoy connection lines and string lines (and possibly the auxiliary lines) with flexible elements in a deflated state attached to the string lines. The number of string lines arranged besides each other and the number of flexible elements will be chosen in accordance with design requirements of the floating assembly to be installed. This also will define the shape and dimensions of the drum (which generally will rotate around a horizontal axis).

A first pair of buoys will be positioned and anchored using anchor lines which for example extend to gravity-based anchors on the seabed which are laid during the installation process or which have been pre-installed.

As a next step a first one of the buoy connection lines is attached to the first pair of buoys, thus already

roughly defining the position of the assembly to be installed. Next, one end of the string lines is attached to said first buoy connection line and following this the assembly will be unwound gradually from the drum while the vessel navigates away from the first pair of buoys.

During unwinding the assembly, the flexible elements will be unwound too. Once a flexible element is removed from the drum, it may be inflated for obtaining the required buoyancy.

The unwinding of the assembly from the drum normally is completed once the string lines have left the drum and with another end have been connected to a second buoy connecting line which has been attached to a second pair of buoys which previously have been positioned and anchored in a manner similar to the first pair. However, the process also may be continued when the assembly comprises a larger number of buoy connecting lines, such that more pairs of buoys will be applied (see for example the embodiment according to figure 4 in which moreover not just pairs of buoys, but triplets of buoys will be positioned).

Thus, the above description of a method for installing a floating assembly according to the present invention merely intends to explain its principles without limiting its features to the features described (the number of buoys positioned at each relevant step may be increased, for example) and some steps may be carried out simultaneously or in another order, if possible.

The invention is not limited to the embodiments described which may be varied widely within the scope of the invention as defined by the appending claims. Features of the embodiments described may be combined to arrive at other embodiments.

CLAIMS

1. Floating assembly for generating solar power, comprising at least one floating element which in an operational position floats on a water surface, with one or more solar panels resting on top of each element and with mooring lines extending between each element and a fixed mooring arrangement, **characterized in that** the fixed mooring arrangement comprises at least one assembly of two buoys which are intended to be anchored by means of anchor lines, wherein at least one string line is provided extending directly or indirectly between the two buoys, wherein the at least one string line is located below the water surface and wherein at least some of the mooring lines of each element extend between said element and the at least one string line.

2. Floating assembly according to claim 1, **characterized in that** the mooring arrangement comprises at least one assembly of four buoys, which buoys substantially are arranged in a rectangular pattern defining longitudinal sides and transverse sides, wherein two buoy connection lines are provided which each substantially connect two buoys located at a same transverse side of the rectangular pattern and which are located below the water surface, and wherein the at least one string line extends between the two buoy connection lines or, directly or indirectly, between two buoys, substantially in parallel to the longitudinal sides.

3. Floating assembly according to claim 2, wherein at least some of the mooring lines extend between the element and the buoy connection lines.

4. Floating assembly according to claims 2 or 3, wherein at least two parallel string lines are provided and

wherein at least some of the mooring lines of each element extend between said element and the two string lines.

5 5. Floating assembly according to claim 4, wherein the element has two opposite longitudinal edges extending in parallel with the string lines and wherein a first group of mooring lines extends between one longitudinal edge and a first one of the string lines, whereas a second group of mooring lines extends between the other longitudinal edge and a second one of the string lines.

10 6. Floating assembly according to claim , wherein a width of a element as measured between opposite longitudinal edges of the element is smaller than a distance between the two parallel string lines, such that the mooring lines belonging to the first group diverge in a downward direction relative to the mooring lines belonging to the second group, or wherein said width is larger than said distance, such that the mooring lines belonging to the first group converge in said downward direction relative to the mooring lines belonging to the second group.

20 7. Floating assembly according to claims 5 or 6, wherein multiple pairs of two adjacent parallel string lines each are provided and wherein a plurality of successive elements are provided which are arranged in parallel longitudinal rows, wherein the elements of a same row with their mooring lines are connected to a same pair of string lines.

25 8. Floating assembly according to claim 7, wherein adjacent string lines, and preferably string lines belonging to a same pair, are interconnected by auxiliary lines which preferably each are provided between successive elements.

30 9. Floating assembly according to claim 8, wherein at least some of the mooring lines of the element are connected to the auxiliary lines.

10. Floating assembly according to claims 5 or 6, wherein at least three parallel string lines are provided and wherein a plurality of elements are provided which, as considered in a longitudinal direction, are arranged in such a staggered pattern that the elements with their two groups of mooring lines alternately are connected to a first and second one, respectively, of the string lines and a second and third one, respectively, of the succession of string lines.

10 11. Floating assembly according to any of the claims 1-3, wherein all mooring lines of an element extend between said element and a single string line.

12. Floating assembly according to any of the previous claims, wherein, in said operational position, each buoy connection line and string line extends substantially at a level between 0,5 and 20 meters, and preferably between 1,5 and 2,5 meters below the water surface.

13. Floating assembly according to any of the previous claims, wherein the buoy connection lines and/or string line(s) are provided with auxiliary buoys.

14. Floating assembly according to any of the previous claims, comprising multiple assemblies each with four buoys.

15. Floating assembly according to any of the previous claims, wherein the buoys at least partially extend above the water surface, or wherein the buoys are fully submerged.

16. Floating assembly according to any of the previous claims, wherein the anchor lines extend between the buoys and fixed anchor points, such as gravity-based anchors, piles, suction anchors and drag anchors.

17. Floating assembly according to any of the previous claims, wherein the buoy connection lines extend in

a curved manner, such that string lines extending between the buoy connection lines at positions close to the buoys are longer than string lines extending between the buoy connection lines at positions further away from the buoys.

5 18. Method for installing a floating assembly according to any of the previous claims, comprising the steps of:

- 10 - providing a vessel having mounted thereon a drum on which an assembly is wound comprising at least string lines with elements in a deflated state attached to the string lines;
- positioning and anchoring a first pair of buoys using the anchor lines;
- 15 - attaching a first one of the buoy connection lines to the first pair of buoys;
- attaching one end of the string lines to said first buoy connection line;
- gradually unwinding the assembly from the drum;
- 20 - inflating the elements after being unwound from the drum, and
- connecting the other end of the string lines, after being unwound from the drum, to a second buoy connection line which has been attached to a second pair of buoys which previously has been
- 25 positioned and anchored using the anchor lines.