

CONTROLLED FLOATING SOLAR MODULE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority from U.S. Provisional Patent Application No. 62/801,747, filed on February 6, 2019, entitled “FLOATING SOLAR PANEL MODULE”, the contents of which are incorporated by reference herein in their entirety.

FIELD OF THE INVENTION

[0002] The present invention, in some embodiments thereof, relates to the field of photovoltaic power systems and, more particularly, but not exclusively, to floating solar panel modules for photovoltaic power systems.

BACKGROUND

[0003] Solar energy is a clean and inexhaustible natural resource and one of the most promising renewable energy technologies. Only a very small fraction of the solar radiation reaching the earth every year would be needed to make a significant step toward global energy sustainability. However, for solar power plants to offer the same generating capacity and supply stability as traditional power plants, the required land area is very large.

[0004] In order to efficiently use the available surface area, therefore, solar power could be moved to lakes, artificial reservoirs, and/or oceans, improving the utilization of land while preserving human living space and land for agriculture, as well as preserving natural reserve areas, for example, by utilizing spaces designated for other industrial uses. Consequently, floating solar arrays have generated great interest in recent years.

[0005] The foregoing examples of the related art and limitations related therewith are intended to be illustrative and not exclusive. Other limitations of the related art will become apparent to those of skill in the art upon a reading of the specification and a study of the figures.

SUMMARY

[0006] The following embodiments and aspects thereof are described and illustrated in conjunction with systems, tools and methods which are meant to be exemplary and illustrative, not limiting in scope.

[0007] There is provided, in an embodiment, a buoyant module comprising a base configured for being buoyantly supported within a body of water, wherein said base defines a space which is in fluid communication with said body of water; a fluid-holding container sized and fitted for being received within said space and for moving in a vertical dimension relative to said base; and wherein a vertical position of said container relative to said base is determined, at least in part, by a fluid level in said container.

[0008] In some embodiments, said base is a vessel and said space is an inner chamber of said vessel.

[0009] In some embodiments, said vessel is a double-walled vessel comprising an outer wall and an inner wall, wherein an interspace between said outer and inner walls is configured for being at least partially filled with a ballast comprising one or more of a liquid and a solid.

[0010] In some embodiments, said base comprises at least two hulls arranged in a spaced-apart position, wherein said hulls are rigidly interconnected to one another, wherein said space is defined between said hulls.

[0011] In some embodiments, said base is at least partially filled with a ballast comprising one or more of a liquid and a solid.

[0012] In some embodiments, said movement in the vertical dimension of said container is in a range of between 10 and 300 cm.

[0013] In some embodiments, the module further comprises a mount coupled to said base and configured for pivotably mounting a solar panel thereon, wherein said solar panel is tiltable about a pivot point relative to said mount.

[0014] In some embodiments, the module further comprises a tilt mechanism configured for translating said movement in the vertical dimension of said container into said pivotable motion of said solar panel about said pivot point.

[0015] In some embodiments, said tilt mechanism is configured for tilting said solar panel between 25° and 75° to either one side or two sides, relative to the horizontal.

[0016] In some embodiments, said tilt mechanism is configured such that a center of gravity of said solar panel is located below or on said pivot point.

[0017] In some embodiments, said tilt mechanism comprises one of: a cable-and-pully tilt mechanism, a crank-like tilt mechanism, and an arcuate slot tilt mechanism, a parallelogram with an underwater symmetrical frame, and a parallelogram with an underwater asymmetrical frame and push/pull rods.

[0018] In some embodiments, said vessel further comprises one or more openings configured for providing said fluid communication between said body of water and said inner chamber, wherein at least some of said one or more openings are dimensioned for regulating a rate of flow of fluid between said body of water and said inner chamber.

[0019] In some embodiments, said regulating is achieved by using a control valve configured for regulating a rate of flow of fluid between said body of water and said inner chamber.

[0020] In some embodiments, the module further comprises a control unit in fluid communication with said container, wherein the control unit is configured for selectively adjusting a fluid level within said container.

[0021] In some embodiments, the module further comprises a pipe connected between said control unit and said container.

[0022] In some embodiments, said pipe is mounted to said base and has at least an extendable portion configured for facilitating said movement in the vertical dimension of said container.

[0023] In some embodiments, said control unit further comprises a pump configured for pumping said fluid into and/or out of said container through said pipe.

[0024] In some embodiments, said control unit is configured for adjusting said fluid level within said container based, at least in part, on the position of the sun on the ecliptic in respect to the geographic location of the module.

[0025] There is further provided, in an embodiment, a system comprising a plurality of buoyant modules comprising each a base configured for being buoyantly supported within a body of water, wherein said base defines a space which is in fluid communication with said body of water, and a fluid-holding container sized and fitted for being received within said space and for moving in the vertical dimension relative to said base, wherein a vertical position of said container relative to said base is based, at least in part, on a fluid level in said container; a framework comprising frame members configured for rigidly interconnecting said modules in a specified arrangement; and a control unit in fluid communication with each of said containers, wherein the control unit is configured for selectively adjusting a fluid level within said containers.

[0026] In some embodiments, said plurality of modules is arranged in a grid array field comprising rows and columns.

[0027] In some embodiments, said base is a vessel and said space is an inner chamber of said vessel.

[0028] In some embodiments, said vessel is a double-walled vessel comprising an outer wall and an inner wall, wherein an interspace between said outer and inner walls is configured for being at least partially filled with a ballast comprising one or more of a liquid and a solid.

[0029] In some embodiments, said base comprises at least two hulls arranged in a spaced-apart position, wherein said hulls are rigidly interconnected to one another, wherein said space is defined between said hulls.

[0030] In some embodiments, said base is at least partially filled with a ballast comprising one or more of a liquid and a solid.

[0031] In some embodiments, said movement in the vertical dimension of said container is in a range of between 10 and 300 cm.

[0032] In some embodiments, said base further comprises a mount coupled to said base and configured for pivotably mounting a solar panel thereon, wherein said solar panel is tiltable about a pivot point relative to said mount.

[0033] In some embodiments, said base further comprises a tilt mechanism configured for translating said movement in the vertical dimension of said container into said pivotable motion of said solar panel about said pivot point.

[0034] In some embodiments, said tilt mechanism is configured for tilting said solar panel between 25° and 75° to either side relative to the horizontal.

[0035] In some embodiments, said tilt mechanism is configured such that a center of gravity of said solar panel is located below or on said pivot point.

[0036] In some embodiments, said tilt mechanism comprises one of: a cable-and-pully tilt mechanism, a crank-like tilt mechanism, and an arcuate slot tilt mechanism, a parallelogram with an underwater symmetrical frame, and a parallelogram with an underwater asymmetrical frame and push/pull rods

[0037] In some embodiments, said vessel further comprises one or more openings configured for providing said fluid communication between said body of water and said inner chamber, wherein at least some of said one or more openings are dimensioned for regulating a rate of flow of fluid between said body of water and said inner chamber.

[0038] In some embodiments, said regulating is achieved by using a control valve configured for regulating a rate of flow of fluid between said body of water and said inner chamber.

[0039] In some embodiments, the system further comprises a control unit in fluid communication with said containers, wherein the control unit is configured for selectively adjusting a fluid level within said containers.

[0040] In some embodiments, the system further comprises a pipe grid configured for connecting said control unit with each of said containers.

[0041] In some embodiments, said control unit further comprises a pump configured for pumping said fluid into and/or out of said container through said pipe grid.

[0042] In some embodiments, said control unit is configured for adjusting said fluid level within said containers based, at least in part, on the position of the sun on the ecliptic in respect to the geographic location of the module.

[0043] In some embodiments, said solar panels are further configured for tilting in unison.

[0044] In some embodiments, said framework further comprises one or more lines configured for mooring said system.

[0045] In some embodiments, said one or more lines are further configured for facilitating adjustment of an azimuth angle of said system.

[0046] There is further provided, in an embodiment, a method comprising: providing a system comprising plurality of buoyant modules, comprising each a base configured for being buoyantly supported within a body of water, wherein said base defines a space which is in fluid communication with said body of water, and a fluid holding container sized and fitted for being received within said space and for moving in the vertical dimension relative to said base, wherein a vertical position of said container relative to said base is determined, at least in part, based on a fluid level in said container; rigidly interconnecting said modules in a specified arrangement using a framework comprising frame members configured for providing a control unit in fluid communication with each of said containers, wherein the control unit is configured for selectively adjusting a fluid level within said containers; and deploying said system in a body of water.

[0047] In some embodiments, said interconnecting comprises interconnecting said plurality of modules in a grid array field comprising rows and columns.

[0048] In some embodiments, said base is a vessel and said space is an inner chamber of said vessel.

[0049] In some embodiments, said vessel is a double-walled vessel comprising an outer wall and an inner wall, wherein an interspace between said outer and inner walls is configured for being at least partially filled with a ballast comprising one or more of a liquid and a solid.

[0050] In some embodiments, said base comprises at least two hulls arranged in a spaced-apart position, wherein said hulls are rigidly interconnected to one another, wherein said space is defined between said hulls.

[0051] In some embodiments, said base is at least partially filled with a ballast comprising one or more of a liquid and a solid.

[0052] In some embodiments, said movement in the vertical dimension of said container is in a range of between 10 and 300 cm.

[0053] In some embodiments, said base further comprises a mount coupled to said base and configured for pivotably mounting a solar panel thereon, wherein said solar panel is tiltable about a pivot point relative to said mount.

[0054] In some embodiments, said base further comprises a tilt mechanism configured for translating said movement in the vertical dimension of said container into said pivotable motion of said solar panel about said pivot point.

[0055] In some embodiments, said tilt mechanism is configured for tilting said solar panel between 25° and 75° to either side relative to the horizontal.

[0056] In some embodiments, said tilt mechanism is configured such that a center of gravity of said solar panel is located below or on said pivot point.

[0057] In some embodiments, said tilt mechanism comprises one of: a cable-and-pully tilt mechanism, a crank-like tilt mechanism, and an arcuate slot tilt mechanism, a parallelogram with an underwater symmetrical frame, and a parallelogram with an underwater asymmetrical frame and push/pull rods.

[0058] In some embodiments, said vessel further comprises one or more openings configured for providing said fluid communication between said body of water and said inner chamber, wherein at least some of said one or more openings are dimensioned for regulating a rate of flow of fluid between said body of water and said inner chamber.

[0059] In some embodiments, said regulating is achieved by using a control valve configured for regulating a rate of flow of fluid between said body of water and said inner chamber.

[0060] In some embodiments, said system further comprises a control unit in fluid communication with said containers, wherein the control unit is configured for selectively adjusting a fluid level within said containers.

[0061] In some embodiments, said system further comprises a pipe grid configured for connecting said control unit with each of said containers.

[0062] In some embodiments, said control unit further comprises a pump configured for pumping said fluid into and/or out of said container through said pipe grid.

[0063] In some embodiments, said control unit is configured for adjusting said fluid level within said containers based, at least in part, on the position of the sun on the ecliptic in respect to the geographic location of the module.

[0064] In some embodiments, said solar panels are further configured for tilting in unison.

[0065] In some embodiments, said framework further comprises one or more lines configured for mooring said system.

[0066] In some embodiments, said one or more lines are further configured for facilitating adjustment of an azimuth angle of said system.

[0067] In addition to the exemplary aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the figures and by study of the following detailed description.

BRIEF DESCRIPTION OF THE FIGURES

[0068] Exemplary embodiments are illustrated in referenced figures. Dimensions of components and features shown in the figures are generally chosen for convenience and clarity of presentation and are not necessarily shown to scale. The figures are listed below.

[0069] Figs. 1A-1D illustrate an exemplary floating solar panel module in accordance with some embodiments of the present invention;

[0070] Fig. 2A illustrates a first exemplary base and container of a floating solar panel module, in accordance with some embodiments;

[0071] Figs. 2B-2D illustrate a second exemplary base of a floating solar panel module, in accordance with some embodiments;

[0072] Figs. 3A-3B illustrate an exemplary bottom closure for a base of a floating solar panel module, in accordance with some embodiments of the present invention;

[0073] Figs. 4A-4D illustrate exemplary mounts, in accordance with some embodiments of the present invention;

[0074] Figs. 5A-5B are schematic illustrations of an exemplary solar panel support frame, in accordance with some embodiments of the present invention;

[0075] Figs. 6A-6D show an exemplary container, in accordance with some embodiments of the present invention;

[0076] Figs. 7A-7C show a container guide for facilitating movement of a container, in accordance with some embodiments of the present invention;

[0077] Figs. 8A-8B schematically illustrate selective adjustment of fluid level within a container, in accordance with some embodiments of the present invention;

[0078] Figs. 9A-9D schematically illustrate exemplary tilt mechanisms, in accordance with some embodiments of the present invention;

[0079] Figs. 10A-10D illustrate a system comprising an array field of floating solar panel modules, in accordance with some embodiments of the present invention; and

[0080] Figs. 11A-11C illustrate a system comprising a floating solar panel module, in accordance with some embodiments of the present invention.

DETAILED DESCRIPTION

[0081] Disclosed herein is a floating module configured for deployment in a body of water, such as the ocean, a lake, or a reservoir. In some embodiments, the floating module is a floating panel module. In some embodiments, the panel module comprises a solar panel. In some embodiments, the panels comprise one or more antennas and/or other elements that require tracking or other rotational movement. Though the floating module disclosed herein may be operable with various moveable elements, for the purpose of simplification of explanation, from this point on, reference will be made only to a floating solar panel module. In some embodiments, and as described in greater detail elsewhere herein, the present module provides for remote adjustment of a tilt angle of the solar panel, so as to cause the solar panel to be oriented towards the sun, for example, during different times of the day. In some embodiments, the present module comprises a simple hydrostatic tilt adjustment mechanism which does not require the use of hydraulics, pneumatics, servo and/or other sensitive electric motors, or any similar type of mechanism. In some

embodiments, the hydrostatic tilt adjustment mechanism may be controlled and operated remotely, through a fluid supply line connected to the module. In some embodiments, the tilt mechanism of the present invention is configured for moderating abrupt changes in the tilt angle of the solar panel caused by, e.g., ambient wind conditions and wave frequencies. In some embodiments, the tilt mechanism of the present invention is configured for optimizing efficiency of the panels by tilting the panels to an angle in which the efficiency is optimal. In some embodiments, the present invention is configured for optimizing efficiency of the panels by using bi-facial panels, e.g. by having no torque tube shading the rear side of such panels. In some embodiments, the tilt mechanism of the present invention is configured for optimizing efficiency of the panels by tilting the panels about a plurality of axes, wherein the axes are distanced from each other at a specific distance such that panels tilted about a first do not cast shadows on panels tilted about a second axis (e.g., backtracking).

[0082] Also disclosed is a system comprising an array field of interconnected floating solar panel modules of the present invention, configured for deployment in a body of water. In some embodiments, individual modules of the present system may be rigidly interconnected, so as to be able to withstand ambient wind, wave, and similar conditions. In some embodiments, the present system may be configured for remotely adjusting a tilt angle of some or more of the solar panels in the array, individually or in unison. In some embodiments, the present system may be configured for adjusting an azimuth orientation of the system within the body of water, e.g., in response to the sun direction, wind, ambient conditions, or the changing seasons.

[0083] A potential advantage of the present invention is, therefore, in that it provides for a floating solar panel module that is tilt-adjustable, requires low-maintenance, and is efficient to operate as part of an array field of modules. The present module has a minimal number of moving parts, a relatively small footprint, is inexpensive to manufacture, and further provides for ease of storage, transportation, and on-site assembly.

[0084] A potential advantage of an array of modules positioned in a body of water that has a framework comprising frame members configured for rigidly interconnecting floating modules, is in that the array covers a small percentage of the body of water, hence the effect

of reduced sun light and/or oxygen absorption from the water surface, are substantially smaller compare to systems built of interconnected floats.

[0085] In some embodiments, the present invention comprises a base. In some embodiments, the base comprises two or more sections, such as hulls, configured for being buoyantly supported within a body of water. In some embodiments, the hulls are interconnected, e.g., alongside, in a spaced-apart arrangement, so as to create a space therebetween for receiving a movable container in a way which permits movement of the container, for example, in a substantially vertical dimension.

[0086] In some embodiments, the hulls combine a system of buoyancy and ballast, so as to achieve a desired floating elevation and orientation of the hulls relative to a fluid level, for example, of a body of water, and to re-assume such desired floating elevation and orientation following a disruption, such as in strong winds and/or currents conditions. For example, in some embodiments, the hulls are hollow, and, in some embodiments, the hulls are configured for fully or partially filling with water, another liquid, or a solid matter to provide desired ballast. In some embodiments, the base is positioned adjacent to the container. In some embodiments, and as described in greater detail elsewhere herein, one or more bases are scattered between a plurality of containers. In some embodiments, the base is separable from the container.

[0087] Figs. 1A-1D illustrate an exemplary floating solar panel module of the present invention, in side (Fig. 1A), front (Fig. 1B), and perspective views (Fig. 1C-1D). Module **100** comprises, in some embodiments, a base **110**. Base **110** may comprise a single vessel, or, in some embodiments, two or more sections, configured for being buoyantly supported within a body of water. In some embodiments, Module **100** comprises one or more mounts, such as, for example, mount **130**, coupled to base **110**. In some embodiments, mount **130** is connected to a top portion of base **110**. A solar panel support frame **170** holding a solar panel **160** may be pivotably mounted to mount **130**, so as to permit adjustment of a tilt angle of support frame **170** relative to the horizontal.

[0088] In some embodiments, a container **140** is received within a flooded interior chamber of base **110**. In embodiments where base **110** comprises two or more sections, container **140** may be received within a space between the spaced-apart sections of base

110. In each case, container **140** is configured for moving in the vertical dimension relative to base **110**. In some embodiments, container **140** is configured to move vertically in a range between 10 and 300 cm. In some embodiments, the container is a fluid holding container. In some embodiments, the vertical position of container **140** may be adjusted by selectively adjusting a fluid level within container **140**. In some embodiments, a tilt mechanism operatively connects support frame **170** and container **140**, wherein changes in the vertical position of container **140** relative to base **110** are translated into changes in the tilt angle (e.g., Figs. 9B and 9C; α , α') with respect to the horizontal (X axis) of support frame **170** and, thus, solar panel **160**.

[0089] In some embodiments, the weight of liquid within container **140** further provides for a balancing effect which helps to maintain the position of container **140** and/or the module as a whole against disruptive external forces (such as wind). In some embodiments, the buoyancy of the container **140** maintains the position of the container **140** and balances the module as a whole against disruptive external forces (such as wind). In some embodiments, the buoyancy of the container **140** prevents the container **140** from being pushed into the water, while the weight of the container **140** prevents to container **140** from being pulled out of the water.

[0090] Fig. 2A depicts an exemplary embodiment of a base and container according to an embodiment. In some embodiments, base **110** may comprise two or more sections, such as hulls **102**. Hulls **102** may be interconnected, e.g., alongside, in a spaced-apart arrangement, so as to create a space **108** therebetween for receiving a movable container, such as container **140** of Fig. 1A, in a way which permits movement of container **140** in a substantially vertical dimension.

[0091] In some embodiments, each hull **102** is configured for being buoyantly supported within a body of water. In some embodiments, a buoyancy level and stability properties of hulls **102** are determined, at least in part, based on at least one of the dimensions, volume, and footprint area of hulls **102**. In some embodiments, hulls **102** combine a system of buoyancy and ballast, so as to achieve a desired floating elevation and orientation of hulls **102** relative to a surface level of the body of water, and to re-assume such desired floating elevation and orientation following a disruption, such as in strong winds and/or currents

conditions. For example, hulls **102** may be hollow hulls configured for fully or partially filling with water, another liquid, or a solid matter to provide desired ballast. In other embodiments, hulls **102** may be solid, only partially hollow, or entirely hollow hulls.

[0092] In some embodiments, each of hulls **102** is configured to have a mounting arm **104** attached thereto about a top portion of each hull **102**, using one or more fastening methods. In some embodiments, each hull **102** is integrally formed with a mounting arm **104**. In some embodiments, two mounting arms **104**, positioned each about a top portion of each hull **102**, are configured for rigidly interconnecting to one another using, e.g., one or more interconnectors **106**, so as to create a rigid base **110** comprising hulls **102** in a defined spaced-apart side-by-side arrangement, as described above. In some embodiments, and as described in greater detail elsewhere herein, one or more of the mounting arm **104** and the interconnectors **106** are integral with a seal of the base **102**.

[0093] Figs. 2B-2D illustrate another exemplary base **110** of the present invention, in perspective (Fig. 2B), side (Fig. 2C), and top (Fig. 2D) views. In some embodiments, base **110** defines a vessel having an interior chamber **118**, and configured for being buoyantly supported within a body of water. In some embodiments, a buoyancy level and stability properties of base **110** are determined, at least in part, based on at least one of dimensions, volume, and footprint area of base **110**. In some embodiments, base **110** combines a system of buoyancy and ballast, so as to achieve a desired floating elevation and orientation of base **110** relative to a surface level of the body of water, and to re-assume such desired floating elevation and orientation following a disruption, such as in strong winds and/or currents conditions.

[0094] In an exemplary embodiment, base **110** may comprise a double-walled construction comprising an outer wall **112** and an inner wall **114**, wherein an interspace **116** between the outer and inner walls is configured for being at least partially flooded, so as to provide ballast to base **110**. In other embodiments, base **110** may be provided with one or more additional and/or other types of ballast. Base **110** may be made of any suitable material, such as various types of polymers. In some embodiments, base **110** may be manufactured using such methods as injection molding, vacuum forming, and/or similar

methods. In some embodiments, base **110** may be shaped to facilitate nesting or stacking, for ease of storage and transportation.

[0095] In some embodiments, and as described in greater detail elsewhere herein, the interior chamber **118** may be configured for being in fluid communication with the body of water outside of base **110**, such that a water level within interior chamber **118** is substantially determined by the surface level of the body of water.

[0096] In some embodiments, base **110** may define an open-bottomed vessel, wherein a bottom opening of base/vessel **110** may be covered with a closure. Figs. 3A-3D illustrate an exemplary bottom closure **125** configured for covering a bottom portion of base **110**, in top perspective (Fig. 3A) and bottom perspective (Fig. 3B) views. In some embodiments, the bottom closure **125** comprises one or more raised supports **139** configured to fit within the base **110**. In some embodiments, and as described in greater detail elsewhere herein, the bottom closure **125** may comprise an opening, such as opening **122**, configured for permitting fluid communication between interior chamber **118** and the body of water.

[0097] Figs. 4A-4D illustrate an exemplary mount **130**, in top perspective (Fig. 4A), bottom perspective (Fig. 4B), and side (Fig. 4C) views. In some embodiments, mount **130** may be configured for attaching to a top portion of base **110**, e.g., using a plurality of fasteners. In some embodiments, mount **130** connects to base **110** in a sealing engagement, wherein the connection provides a seal against the egress of liquids into the interior of base **110**. In some embodiments, mount **130** comprises one or more support posts **132** configured for pivotably mounting a solar panel support frame, such as support frame **170** in Figs. 1A and 1D.

[0098] In some embodiments, for example, as depicted by Figs. 4B, 4C, and 4D, the mount **130** is configured to seal the base **110** and/or hulls **102**. In some embodiments, the mount **130** comprises a shoulder **133** configured to fix onto the base **110** and/or hulls **102**. In some embodiments, the mount **130** comprises an opening **137** sized to fit the container **140**. In some embodiments, the container **140** is moveable through the opening **137** of the mount **130**.

[0099] Typically, solar panels are constructed similarly to a picture in a frame, with the solar cells being laminated between a transparent front cover and a protective back layer,

where the laminate is being mounted within a surrounding rectangular and substantially flat metal frame. Accordingly, in some embodiments, solar panels **160** may be mounted to such a support frame **170**, shown in Figs. 1A-1D.

[00100] Figs. 5A-5B are schematic illustrations of an exemplary solar panel support frame **170** which may be used in conjunction with the present invention.

[00101] In some embodiments, such as depicted in Fig. 5A, movement of the frame **170** changes the forces that are applied to the axis **172** by the weight of the panels and frame **170**. In some embodiments, the center of gravity of the frame **170** and/or the panels is adjustable in relation to the pivot. In some embodiments, adjusting the center of gravity about the pivot, for example, as depicted in **5B** eliminates the dynamically interrupting forces.

[00102] In some embodiments, the support frame **170** may comprise a horizontal longitudinal shaft which may provide a pivot point along, e.g., a central longitudinal axis of support frame **170**. In some embodiments, the pivot point comprises an axis of rotation about which the frame **170** rotates. In some embodiments, movement of the support frame **170** changes the position of the center of gravity of the support frame **170** relative to module **100**. In some embodiments, the center of gravity of the support frame **170** is adjustable in relation to the pivot.

[00103] A potential advantage of the center of gravity of the support frame **170** and/or panels being adjustable is in that the center of gravity can be adjusted such that one or more external forces applied to the support frame **170** ad/or panels can be partially and/or fully countered by the center of gravity of the support frame **170** ad/or panels. In some embodiments, the center of gravity of the support frame **170** and/or panels is adjusted by taking into account the external forces acting on the support frame **170** ad/or panels.

[00104] In some embodiments, support frame **170** may be pivotably mounted to a mount, such as mount **130** of Fig. 1A, or mounting arms **104**. In some embodiments, a pivot point about which support frame **170** pivots may be located on a same plane as the support frame **170**. In some embodiments, a pivot point about which support frame **170** pivots may be located below a plane of support frame **170**. In other embodiments, the pivot point may be

located above the plane of support frame **170**, so as to lower a center of gravity of support frame **170**, thereby creating a self-centering effect about axis **172**.

[00105] A potential advantage of the pivot point having a same height as the center of gravity of support frame **170**, is in the elimination of dynamical moments, caused by the weight of the support frame **170**, applied to the pivot point, in relation to similar forces applied onto a pivot point not aligned with the support frame **170**.

[00106] Figs. 6A-6D shows an exemplary container **140** of the present invention, in top perspective (Fig. 6A), bottom perspective (Fig. 6B), side (Fig. 6C), and top (Fig. 6D) views. In some embodiments, container **140** defines a receptacle for fluids, dimensioned for being received within interior chamber **118** (Fig. 2B) or space **108** (Fig. 2A) of base **110**, and for slidingly moving in the vertical dimension relative to base **110**.

[00107] Figs. 7A-7C illustrate an exemplary container guide **148** which may be attached to container **140** and slide against the interior wall **114** of base **110** and configured for aligning and facilitating the vertical movement of container **140** within interior chamber **118**. In some embodiments, container guide **148** may comprise a plurality of slide rails **149**, e.g., between 2 and 6 slide rails **149**, defining a receiving space of container **140** and facilitating the controlled vertical movement of container **140** under the guidance of, e.g., one or more receiving vertical slot in an internal wall of base **110**.

[00108] With reference back to Figs. 6A-6D, in some embodiments, container **140** may be configured for being emptied and/or filled with fluid, such as water, from a remote location, via opening **142** in container **140**. In some embodiments, opening **142** may comprise a spout **144** (seen in Fig. 6B). Container **140** may be made of any suitable material, such as various types of polymers. In some embodiments, container **140** may be manufactured using such method as injection molding, vacuum forming, and/or similar method. In some embodiments, container **140** may be shaped to facilitate nesting or stacking, for ease of storage and/or shipment.

[00109] In some embodiments, opening **142** can be positioned on any one or more of the walls of the container **140**. In some embodiments, fluid is filled and/or emptied from the container **140** through any one or more of the side walls, the top portion of the container

140, and the bottom portion of the container **140**, using a flexible pipe with its end fastened to the container **140** bottom.

[00110] As noted above, interior chamber **118** of base **110** is in fluid communication with the body of water surrounding base **110**, such that a fluid level within interior chamber **118** is substantially equal to the surface level of the body of water. In the case of multi-sectional base **110** seen in Fig. 2A, space **108** is located within the surrounding body of water.

[00111] Accordingly, container **140**, in some embodiments, is configured for being buoyantly supported within interior chamber **118** or space **108**, as the case may be, wherein a buoyancy height of container **140** may be determined by a fluid level within container **140**. In some embodiments, by changing the fluid level within container **140**, the buoyancy height of container **140** may be adjusted. In some embodiments, container **140** may slidably move within interior chamber **118** or space **108**, as the case may be, such that, at its highest position, a top portion of container **140** may extend above a top portion of base **110**.

[00112] Figs. 8A-8B schematically illustrate selective adjustment of a fluid level within container **140**, within the context of a base **110** having a chamber **118** (Fig. 8A) or space **108** (Fig. 8B). In some embodiments, spout **144** may be connected to a fluid conduit feeding system comprising, e.g., rigid pipe **150** configured for supplying fluid from a remote location. A terminal of rigid pipe **150** may be inserted into base **110** through opening **120** (also shown in Figs. 1A, 1C, 1D and 2A). Within base **110**, rigid pipe **150** may be connected to flexible section **148** configured for supplying fluid to container **140** while permitting vertical movement of container **140** relative to base **110**. Fluid volume supplied or removed from container **140** via rigid pipe **150** determines the level of fluid inside container **140** and affects the buoyancy of container **140** within base **110**. Controlled flow of the fluid volume into and out of container **140** controllably affects the buoyancy of container **140** bringing controllable vertical movement of container **140** relative to base **110** as shown in Figs. 9A and 9B.

[00113] Figs. 9A-9B schematically illustrate an exemplary tilt mechanism configured for translating a vertical motion of container **140** into changes in the tilt angle of support frame **170**. In Fig. 9B, container **140** is maximally filled up with fluid, and consequently its buoyancy level relative to base **110** is at its lowest level, which translates into a maximal

tilt angle in a first direction relative to the horizontal. In Fig. 9C, container **140** is minimally filled up with fluid, and consequently its buoyancy level relative to base **110** is at its highest level, which translates into a maximal tilt angle in an opposite direction relative to the horizontal. Accordingly, by controlling the fluid level in container **140**, all tilt angles can be achieved within this range.

[00114] In some embodiments, a tilt mechanism of the present invention may be configured for tilting support frame **170**, from 0° up to between 25° and 75° on either side, for example, e.g. front and back of module **100**, relative to the horizontal. In some embodiments, such tilting of the support frame **170**, from 0° up to between 25° and 75°, is done on one side only - e.g. front or back of module **100**.

[00115] Fig. 9A schematically illustrates an exemplary embodiment of a cable-and-pulley tilt mechanism. A cable **900** is connected to container **140** at an upper and lower points **900a**, **900b**, and to support frame **170** at two opposing points on either side of pivot point **135**. Cable **900** is then routed at a bottom area of base **110** through pulleys, e.g., pulleys **902a**, **902b**. Thus, an upward vertical movement of container **140** exerts a pull force on cable **900** through connecting point **900a**, whereas a downward movement of container **140** exerts an opposite pull force on cable **900** through connecting point **900b**. In either case, the pull force exerted in either way with respect to cable **900** is translated into a pivoting movement of support frame **170**. Because the cable/pulley arrangement translates the vertical movement of container **140** into a pull force, the translation into pivoting movement is expected to be smoother and with less mechanical slack and free-play. In some embodiments, the container **140** may be located substantially above pulley **902a**, to ensure a smooth operation and a self-centering force.

[00116] In some embodiments, another exemplary tilt mechanism shown in Figs. 9B-9C may comprise a crank-like arrangement comprising a tilt crank bracket **173** coupled to support frame **170**, and a link rod **172** connected to crank bracket **173** at a first pivot point **172a** and to container **140** at a second pivot point **172b**.

[00117] Fig. 9D illustrates another exemplary embodiment of a tilt mechanism which may be used to translate the vertical motion of container **140** into rotational motion of support frame **170**. For example, support frame **170** may comprise one or more brackets **175**

comprising an arcuate guide slot **138**, wherein container **140** may be operationally connected to a guide pin **135** fitted within the guide slot **138**. In some embodiments, the movement in the vertical dimension of container **140** is thus translated into angular movement of frame **170**. In some embodiments, the tilt mechanism comprises a push-pull mechanism of a rod coupled to one or more of the containers **140** and the support frame **170**. In some embodiments, pushing and/or pulling the rod changed the position of the frame **170** in relation to the container **140**.

[00118] In some embodiments, the interior chamber **118** may be configured for being in fluid communication with the body of water outside of base **110**, such that a water level within interior chamber **118** is substantially determined by the surface level of the body of water. In some embodiments, fluid communication for interior chamber **118** may be provided by, e.g., one or more openings on the side and/or bottom areas of interior chamber **118**. In some embodiments, such openings may be dimensioned so as to provide for a controlled fluid flow between interior chamber **118** and the body of water, so as to avoid any abrupt fluid level changes within interior chamber **118**, which may affect a tilt angle of the solar panel, as explained in greater detail elsewhere herein. In some embodiments, one or more of these openings may comprise a control valve and/or a similar device to provide for controlled fluid communication with the body of water.

[00119] In some embodiments, base **110** may define an open-bottomed vessel, wherein a bottom opening of base/vessel **110** may be covered with a closure. In some embodiments, the bottom closure **125** comprises one or more raised supports **139** configured to fit within the base **110**.

[00120] In some embodiments, bottom closure **125** may comprise an opening, such as opening **122**, configured for permitting fluid communication between interior chamber **118** and the body of water. In some embodiments, opening **122** may be dimensioned so as to provide for a controlled fluid flow between interior chamber **118** and the body of water, so as to avoid any abrupt fluid level changes within interior chamber **118**. In some embodiments, the bottom closure **125** may comprise a control valve and/or a similar device in fluid communication with the body of water.

[00121] Figs. 10A-10C illustrate a system comprising an array field **190** of solar panel modules **100** (Figs. 1A-1D) of the present invention. In some embodiments, array field **190** of the present invention may comprise a plurality of modules **100** arranged according to several assembly schemes, e.g., in rows and columns. Typically, a field will assume a generally rectangular or square geometry, though such a geometry is not required. In some embodiments, the array field **190** can assume an irregular shape as it may be conformed to the area shape of the body of water on which it is installed.

[00122] In some embodiments, the modules **100** in array field **190** may be interconnected using a rigid frame system **220**. In some embodiments, two or more modules **100** in an array field may be in fluid communication, wherein a fluid level in respective containers **140** in each module **100** may correspond among all modules **100** in fluid communication. In some embodiments, such fluid communication may be done across a row, column, diagonally, and/or an entire array field **190**. In some embodiments, such fluid communication works to substantially equalize a fluid pressure and/or a fluid level inside each respective container **140** within the communicating modules **100**.

[00123] In some embodiments, the bases **110/102** and/or containers **140** form a matrix of bases **110/102** and containers **140**. In some embodiments, the bases **110/102** and/or containers are positioned in relation to each other as to form patterns. In some embodiments, specific patterns of the positioning of the bases **110/102** and/or containers **140** correspond to specific buoyancy levels throughout the matrix, and, in some embodiments, the specific patterns generate specific tilting patterns of the support frame **170** and/or of the panels.

[00124] In some embodiments, the interconnectors **220** may be configured for withstanding movement caused by wind, waves, and/or currents. In some embodiments, the system may be designed to withstand wave conditions having a wave height of up to 50cm and a wave length of up to 400cm. Accordingly, as illustrated in Fig. 10A, in wave conditions which cause uneven surface level, the present system as a whole may be configured for supporting the weight of individual modules as they heave and bob in the waves. As noted above, base **110** is configured for a controlled fluid flow between interior chamber **118** and the body of water, so as to avoid any abrupt fluid level changes within interior chamber **118** in uneven water level conditions.

[00125] In some embodiments, an array field of the present invention may comprise a closed fluid filling/emptying system, wherein fluid may be transferred from one or more containers **140** to other containers **140** within the array. For example, a number (e.g., half) of modules in an array may be inverted, such that for half the array, filling containers **140** with more fluid causes a tilting motion in a first direction, wherein for the second half, emptying containers **140** causes a tilting motion in the same first direction. Thus, by transferring fluid within the closed system array from the first half of containers **140** to the second half, there is achieved a coordinated tilting movement of all solar panels in array **190** in the same direction.

[00126] In some embodiments, the modules **100** in array field **190** may be spaced in accordance with ambient wave conditions of the body of water in which the system will be deployed. Thus, e.g., the spacing of modules relative to one another can be tailored to minimize roll, pitch, yaw, heave, surge and sway under the wave conditions most likely to be encountered in the particular environment of use.

[00127] In some embodiments, an array field **190** of the present invention may be configured for achieving different ground cover ratios (GCR) of solar panels to field area.

[00128] In some embodiments, the field **190** of the present invention may be configured for adjusting the GCR of solar panels, by adjusting the distance between two or more rows of modules and/or panels. In some embodiments, the distance between two or more rows is adjusted such that the GCR value is maximal. In some embodiments, the distance between two or more rows, and the related GCR, is adjustable such that for a specific origin direction of sunlight, no row of panels casts a shadow over another row of panels. In some embodiments, a reduced GCR increases efficiency and yield when using bi-facial solar panels.

[00129] In some embodiments, solar panels **160** in array field **190** may be interconnected so as to move in unison along, e.g., each row of array field **190**. In some embodiments, solar panels rows in array field **190** may be interconnected so as to move in unison along.

[00130] In some embodiments, a supply grid of pipes **150** may be connected to each module within an array field **190**, to enable fluid feed into each container **140**, as described above with reference to Fig. 8.

[00131] In some embodiments, the supplied fluid may contain one or more of additives, supplements, and/or filtered fluid. for example, in some embodiments, the fluid comprises additives configured to prevent fluid freezing, bacterial growth within the fluid, and/or prevention of mineral deposits within the fluid system.

[00132] Referring to Fig. 10C, there is shown in schematic top plan view a mooring approach used to stabilize and protect array field **190** of the present invention. Assuming a rectangular field shape, the mooring and anchoring system of the present invention may use one or more running lines **240** for each of the four corners of the rectangle quadrants. The line **240** may extends outwardly from the array to reach, e.g., onshore anchor points, a mooring buoy, etc. In some embodiments, lines **240** may be connected to a pulley system, a winch system, and/or a similar system, to facilitate lateral translation of the array into different azimuth angles, as may be beneficial for azimuth tracking of the sun and during, e.g., different seasons of the year, or in different sea or wind conditions.

[00133] In some embodiments, as depicted in Fig. 10D, a mooring and anchoring system of the present invention may comprise a horizontal ‘yo-yo’-like arrangement in which two or more lines **250**, **260** wrap around an array in opposing directions, so as to facilitate rotational positioning of the array. Thus, a rotational force applied to the array by an ambient element (e.g., wind), will tend to loosen a first line (e.g., line **250**) while building tension in a second line (e.g., line **260**). Once the rotational force is removed, the tensioned line **260** tends to return array **190** to its original orientation. In some embodiments, lines **250**, **260** may be used to rotate array **190** into a desired position. In some embodiments, such rotational positioning may permit rotating array **190** more than **180** degrees in either side.

[00134] In some embodiments, a system of the present invention may comprise a control unit which may be located, e.g., onshore. The control unit may be connected to a plurality of pumps and valves, configured for remotely controlling and adjusting a fluid level within containers **140** by feeding and emptying containers **140** through pipes **150**, as may be necessary. In some embodiments, one or more pumps are configured for pumping liquid into and/or out of the container **1140/140**.

[00135] In some embodiments, the system comprises two or more groups of modules, wherein the support frames **170** of each group rotate in different directions. Therefore, for

one group, fluid filling the containers causes a tilt of the support frames **170** in a first direction, and for a second group, fluid filling the containers causes a tilt of the support frames **170** in a second direction. In some embodiments, the containers are in fluid communication such that fluids emptying from one group of containers are the same fluids used to fill the second group of containers.

[00136] In some embodiments, different portions of the system are in fluid communication such that the communicating containers comprise a same level of fluid in relation to each other. In some embodiments, the portions which are in fluid communication are one or more of rows of containers within the system, portions of rows of containers within the system, and one or more patterns of containers within the system.

[00137] In some embodiments, the system comprises one or more additional liquid sources in fluid communication with one or more of the containers. In some embodiments, the additional liquid sources may stream liquid into one or more containers at an equal rate. In some embodiments, the additional liquid source is configured to adjust the flow rates of the plurality of containers of the system. In some embodiments, the additional liquid source is configured to adjust the flow rates of the plurality of containers of the system such that the frames of the panels are tilted at the same angle and/or at the same velocity.

Tilt Mechanism

[00138] Reference is made to Figs. 11A, 11B, and 11C, which illustrate a system comprising a floating solar panel module, in accordance with some embodiments of the present invention.

[00139] In some embodiments, the angle of the support frame **1170/170** is adjusted in accordance with the height of the container **1140/140** and in relation to the fluid level **1116** surrounding the base **1114/110/102**. In some embodiments, the height of the container **1140/140** is adjustable via change of one or more of the vertical axial range of motion of the container **1140/140**, the rotational range of motion of the support frame **1170/170**, the friction levels of the tilt mechanism, the volume of the container **1140/140**, the weight of the container **1140/140**, and the circumference of the container as a function of the axial length of the container **1140/140**.

[00140] In some embodiments, the support frame **1170/170** is coupled to the container via one or more cables **1102/1104**. In some embodiments, the support frame **1170/170** is attached by one or more cables **1102/1104** to the container **1140** by a hinge. In some embodiments, the base **1114/110/102** and/or container **1140/140** are coupled to a base frame **1120**. In some embodiments, the base frame **1120** is coupled to the support frame **1170/170** via the base **1114/110/102**.

[00141] In some embodiments, the base frame **1120** is configured to balance the movement of the support frame **1170/170**. In some embodiments, the base frame **1120** is parallel to the support frame **1170/170**. In some embodiments, the base frame **1120** comprises a rod **1126** coupled to the base **1114/110/102**. In some embodiments, the base frame **1120** comprises a moveable portion **1128** coupled to the rod **1126** and/or to the base **1114/110/102** by one or more hinges **1124**. In some embodiments, the moveable portion **1128** rotates about the hinges **1124**.

[00142] In some embodiments, one or more cables **1104** extend from two or more ends of the container **1140/140** such that one portion of the cable **1104-1** is coupled to the container **1140/140** on one end and to the base frame **1120** at a second end of the portion of the cable **1104-1**. In some embodiments, one or more cables **1104** extend from two or more ends of the container **1140/140** such that one portion of the cable **1104-2** is coupled to the container **1140/140** on one end and to the frame **1170/170** at a second end of the portion of the cable **1104-2**.

[00143] In some embodiments, tension within the cables **1102/1104** is generated if the container is mechanically unbalanced, for example, if the buoyancy force of container **1140/140**, and the gravity force of the container **1140/140** and the fluid within it, are unbalanced. In some embodiments, during a mechanically unbalanced state, the container **1140/140** will move vertically, at least in part, in correspondence with the movement of the module **1100/110/100**, until the forces acting on the container **1140/140** achieve equilibrium. In some embodiments, the forces acting on the container comprise one or more of forces extracted by the movements of the base **1114/110/102**, gravitational and buoyancy forces, and external forces such as those created by wind currents. In some embodiments, the fluid within the container **1140/140** weighs down the container **1140/140**. In some

embodiments, the weight of the fluid within the container **1140/140** balances the buoyancy forces of the container **1140/140**.

[00144] In some embodiments, the balance of the forces acting on the container is controllable by controlling the rate in which liquid enters and/or exits the container. In some embodiments, addition or removal of liquid from the container increases or decrease the force required to balance the container and/or the module **1100/110/100**. Therefore, in some embodiments, controlling the amount of liquid entering and/or exiting the container controls the angle of the support frames **1170/170** of the module **1100/110/100**.

[00145] In some embodiments, the movement of the container correlates with the area of the cross section of the container which crosses the fluid level **1116**. In some embodiments, such as depicted by Figs. 11A-11C, the container **1140/140** comprises a conical shape configured such that the amount of liquid required to fill each level **1118** across the length of the container **1140/140** is different. In some embodiments, the amount of liquid required to fill the length of the container **1140/140** increases from one end of the container **1140/140** to the other. In some embodiments, the amount of liquid required to fill the length of the container **1140/140** increases from a first end of the container up to a midsection of the container, then begins decreasing up to the second end of the container **1140/140**.

[00146] In some embodiments, the vertical movement of the container corresponds to the rate of change of the liquid volume within the container. In some embodiments, the speed of the vertical movement of the container from a first location point 1 to a second location point 2 can be described as a function of the flow rate into/out of the container and/or the volume change of the liquid within the container, for example, as depicted by the following equation:

$$v_v = \frac{\Delta Z}{t} = \frac{\Delta Z}{\Delta V / \text{FlowRate}} = \frac{Z_2 - Z_1}{(V_2 - V_1) / \text{FlowRate}} \left[\frac{\text{cm}}{\text{cm}^3 / \frac{\text{cm}^3}{\text{sec}}} \right]$$

[00147] Wherein ΔZ comprises the difference of the height of the container between a first location point 1 and a second location point 2, ΔV comprises the difference in fluid volume within the container between a first location point 1 and a second location point 2, Flowrate comprises the rate of fluid flow into and/or out of the container, and v_v comprises the

velocity of the movement of the container, measured in cm/second. In some embodiments, the above equation is simplified and does not include the effect on v_v by the changing weight of the container, caused by the changing height of the container in relation to the fluid level **1116**.

[00148] In some embodiments, the speed of the vertical movement v_v , of the container from a first location point 1 to a second location point 2 is a function of the changing weight of the container between point 1 to point 2. In some embodiments, the vertical movement of the container between point 1 to point 2. In some embodiments, the vertical movement of the container from a first location point 1 to a second location point 2 is a function of the liquid volume change within the container. In some embodiments, the function of the liquid volume change within the container is non-linear. In some embodiments, it is appropriate to measure the weight of the container in the water and out of the water at both of the location points 1 and 2 and integrate both measures in the vertical speed calculating. The difference in the weights corresponds with, at least, part of the chamber of the container, below the fluid level **1116**, which remains hollow at each of the location points 1 and 2. In some embodiments, the portion of the container below fluid level **1116** which is not filled with liquid, that is needed to maintain equilibrium of buoyancy versus weight forces, changes within a same container moving from point 1 to point 2 or vice versa. In such a movement, the difference in magnitudes between the gravitational forces and the buoyancy is balanced by the liquid volume within the container, which may increase or decrease in order to achieve equilibrium. Along with a volume change of the liquid within the container, the container therefore moves vertically under the exerted forces and/or due to the liquid volume changes within the container. In some embodiments, the calculation of the velocity of such movement therefore depends, at least in part, on the change in liquid volume within the container **1140/140**. In some embodiments, the speed of the vertical movement v_v , considering the changing weight of different portions of the container, for example, the portions above and below the fluid level **1116**, is depicted by the following equation:

$$v_v = \frac{\Delta Z}{t} = \frac{\Delta Z}{\left(\Delta V - \frac{\Delta M}{\rho_w}\right)/FlowRate}$$

$$= \frac{Z_2 - Z_1}{\left(V_2 - V_1 - \frac{M_2 - M_1}{\rho_w}\right)/FlowRate} \left[\frac{cm}{\left(cm^3 - \frac{kg}{cm^3}\right)/\frac{cm^3}{sec}} \right]$$

[00149] Wherein M_1, M_2 are the masses of the portions of the container above fluid level **1116**, at the first location point 1 and the second location point 2, and ρ_w is the density of the fluid.

[00150] In some embodiments, the angular velocity is derived from the vertical velocity and the length between the axis of rotation and the point onto which force is exerted due to the vertical movement.

$$\omega = \frac{v_v}{r}$$

Wherein r is the distance between the axis of rotation and the point in which the cables are connected, e.g., points **1130-1/1130-2** as depicted in Figs. 11A and 11B respectively.

[00151] In some embodiments, the amount of force required to change the position of the support frames **1170/170** is derived from the inner forces acting within the module **1100/110/100** and the external forces exerted onto the module **1100/110/100**.

[00152] In some embodiments, the inner forces include friction between interacting portions of the module **1100/100** and forces created by the position of the center of mass of frame **1170/170** in relation to its rotational axis. In some embodiments, when the center of mass is positioned above its rotational axis, the support frames **1170/170** may tilt and fall to the side of the modules **1100/110/100**. In some embodiments, for larger angles, the force of the fall of the support frames **1170/170** may increase. In some embodiments, when the center of mass is positioned below its rotational axis, and no other forces applied to it, the support frames **1170/170** tilt to reach a horizontal state.

[00153] In some embodiments, the external forces exerted on the module **1100/110/100** include forces of wind currents which are exerted mainly on the support frames **1170/170**. In some embodiments, the external forces exerted on the module **1100/110/100** include the

dynamic weight additions to the system, such as maintenance people, animals, such as, for example, birds resting on the module **1100/110/100**, precipitants, and water sprayed, forces onto the module **1100/110/100** applied by waves.

[00154] In some embodiments, and in order to control and/or supervise the movement of the module **1100/110/100** and/or of the support frames **1170/170**, the module **1100/100** is structured such that the moment, or the force of the container times the length of the shaft in relation to the pivot point **1112/172a/172b** of the axis of rotation (e.g., the length L of the support frames **1170/170** as depicted in Fig. 11A), is larger than the sum of the external and internal forces exerted onto the module **1100/110/100** and/or support frames **1170/170**. In some embodiments, the same process can be calculated for when the movement of the module **1100/110/100** is controlled by a plurality of gears types. In some embodiments, the plurality of gear types is configured to convert the vertical movement of the container into angular movement of the support frames **1170/170**.

[00155] In some embodiments, using the container **1140/140** and/or the buoyancy of the container **1140/140** and/or the weight of water inside the container **1140/140** allows countering the rotational forces which are extracted onto the support frames **1170/170**. In some embodiments, the main external rotational force is exerted onto the support frames **1170/170** by wind. In some embodiments, the container **1140/140** is coupled to the support frames **1170/170** via one or more cables and/or rods, such that the external forces applied to the support frames **1170/170** are exerted onto the container **1140/140** and are countered by the buoyancy or weight of the container **1140/140**, thereby preventing excessive movement of the support frames **1170/170**.

[00156] In some embodiments, the buoyancy of the container **1140/140** and/or gravitational forces of the container change in accordance with a change of strength and/or direction of the wind, to maintain equilibrium of forces. These changes of forces directly counter the rotational force applied by the wind on frame **1170/170** with no rotational stress applied on the pivot point **1112/172a/172b**. In some embodiments, the position of the module **1100/110/100** is adjusted to compensate the effect of variable wind speed in such a way that the module **1100/110/100** is at mechanical equilibrium at the desired angle of frame **1170/170**, and no rotational countering forces (to differentiate from e.g., linear forces acting

on the module), stress the different portions of the module **1100/110/100**, for example, the pivot point **1112/172a/172b**.

[00157] In some embodiments, the forces of the winds cause undesired movement of the support frame **1170/170**. In some embodiments, the forces of the winds cause the support frame **1170/170** to move such that the support frame **1170/170** is not positioned at a desired angle. In such cases, the container **1140/140**, which is coupled to the support frame **1170/170** moves vertically in relation to the water level **1116**, which in turn may cause the buoyancy and weight forces to get out of balance, causing a dynamic force, opposite in direction to the undesired movement. In some embodiments, the magnitude of these dynamic forces of buoyancy and weight, correspond to the change of angle of the support frame **1170/170** from its desired position. For example, for forces that cause an increase of the angle of the support frame **1170/170** in relation to the desired position, thereby pushing the container **1140/140** downward into the water, the countering buoyancy of the container increases in magnitude as the frame **1170/170** is pushed away from its desired position. In some embodiments, such dynamically damping forces push frame **1170/170** back to equilibrium at the desired position.

[00158] In some embodiments, a cross section plane of the container **1140/140**, which is parallel to the fluid level **1116** in which the container **1140/140** floats, defines the magnitude of the buoyancy and weight forces acting to maintain equilibrium in the desired position. In some embodiments, the geometry of the container **1140/140** is structured such that the cross section of the container **1140/140** varies along the vertical movement range. In some embodiments, the container **1140/140** is structured such that the area of transverse cross section of the container **1140/140** is sufficient for the buoyancy and weight to counter to wind forces.

[00159] In some embodiments, the area of the transverse cross section is adjusted in each container **1140/140** in accordance with some embodiments of the present invention the desired vertical range of motion. For example, in the illustration depicted by Fig. 11B, the magnitude of the buoyancy and weight forces generated at each repeating section of the vertical movement range (e.g. 1 cm), is greatest in the midsection of the vertical movement

range while the support frames **1170/170** are horizontal and/or parallel to the fluid level **1116**.

[00160] In some embodiments, apart from the damping forces achieved by the container **1140/140**, the module comprises an added, undesired forces dampening mechanism. In some embodiments, the module comprises a force dampening mechanism. For example, in some embodiments, the mechanism comprises an additional one or more of a bucket, a bag, or container.

[00161] In some embodiments, such as in the exemplary embodiment depicted by Fig. 11C, the module **1150/1100/110/100** comprises one or more additional containers **1108**. In some embodiments, the one or more additional containers **1108** are coupled to the support frame **1170/170** at one or more ends thereof. In some embodiments, the one or more additional containers **1108** are coupled to the support frame **1170/170** via one or more cables **1122**.

[00162] In some embodiments, the additional containers **1108** comprise a chamber configured to fill with fluid. In some embodiments, the additional containers **1108** comprise one or more apertures **1110** which are configured to provide fluid communication between the chamber of the additional container **1108** and the body of water. In some embodiments, the flow of fluid into and out of the containers **1108** is determined by the size of apparatus **1110**. In some embodiments, the desired speed of frame **1170/170** moves container **1108** vertically upward or downward, causing water from the body of water to flow into or out from the containers at a certain speed according to containers **1108** cross section at water level **1116**. In some embodiments, the apparatus **1110** is sized so as to allow the free flow of water caused by the desired, normally slow, speed of the frame **1170/170**.

[00163] In some embodiments, the external forces acting on the module **1150/1100/110/100** push frame **1170/170** from its desired position at speed higher than desired. In some embodiments, for such undesired speeds, due to the restrained flow allowed through apparatus **1110**, fluid flow into and/or out of the additional containers **1108** through the one or more apertures **1110**, is insufficient to maintain equilibrium. Accordingly, either water accumulates in container **1108** above water level **1116**, or a section empty of fluid, is generated in container **1108**, below water level **1116**. In both cases buoyancy or weight

forces generated are at opposite direction of the undesired movement and may be used as added damping forces. In some embodiments, and similarly to the container **1140/140** undesired movements and the counter, weight and buoyancy, forces generated by them, the magnitude of the damping forces generated by containers **1108** is getting stronger as the undesired speed of the table is higher. Thereby, in some embodiments, for cases in which the angle of the position of the support frame **1170/170** in relation to the desired position of the support frame **1170/170** increases in higher undesired speeds, then the countering force exerted onto the module **1150/1100/110/100** by the additional container **1108** increases. In some embodiments, for example, such as depicted in 11D, having containers **1108** on both sides of frame **1170/170** allows using only the added weight generated in higher than desired frame speeds. According to the direction of undesired speed water in containers **1108** accumulate above water level **1116** in either sides of the frame, generating an equivalent damping force pulling the frame back to the desired position through cables **1122**.

[00164] The descriptions of the various embodiments of the present invention have been presented for purposes of illustration but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments. The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

CLAIMS

What is claimed is:

1. A buoyant module comprising:
at least one base configured for being buoyantly supported within a body of water;
at least one fluid-holding container sized and fitted for being connected with said at least one base for movement in a vertical dimension relative to said at least one base;
at least one mount coupled to said at least one base in a sealing engagement against the egress of liquids into the interior of said at least one base and configured for pivotably mounting at least one solar panel thereon, wherein said mount comprises at least one opening sized and shaped to fit said at least one container and enable said movement in said vertical dimension,; and
at least one support frame, attached to the at least one mount and carrying said at least one solar panel;
wherein said at least one support frame is tiltable about a pivot point relative to said mount;
and wherein a vertical position of said at least one fluid-holding container relative to said base is determined, at least in part, by a fluid level in said at least one fluid-holding container.
2. The module of claim 1, wherein said at least one base defines a space therewithin; further wherein said at least one fluid-holding container is sized and fitted for being received within said space.
3. The module of claim 1, wherein said at least one base comprises at least two hulls arranged in a spaced-apart position, wherein said hulls are rigidly interconnected to one another, and wherein said at least one fluid-holding container is disposed therebetween said hulls, further wherein said hulls are made of at least one selected from a group consisting of solid, at least partially hollow, entirely hollow hulls and any combination thereof.
4. The module of any one of claims 1-3, wherein at least one of: (a) said at least one base is at least partially filled with a ballast comprising at least one selected from a group consisting a liquid, a solid, and any combination thereof; (b) said base is in fluid communication with said body of water; (c) any combination thereof.

5. The module of claim 1, further comprising a tilt mechanism configured for translating said movement in said vertical dimension of said at least one fluid-holding container into said pivotable motion of said at least one support frame about said pivot point; further wherein said tilt mechanism is configured for tilting said at least one support frame between 25° and 75° to either side relative to the horizontal; in response to at least one selected from a group consisting of the sun direction, wind, ambient conditions, changing seasons and any combination thereof; further wherein said tilt mechanism is configured such that a center of gravity of said solar panel is located below or on said pivot point.

6. The module of claim 5, wherein said tilt mechanism comprises one at least one mechanism selected from a group consisting of: (a) a cable-and-pully tilt mechanism, comprising: (i) at least one first cable coupled to the upper portion of said at least one fluid-holding container; (ii) at least one second cable coupled to the bottom portion of said at least one fluid-holding container; said at least one first cable and said at least one second cable are coupled to said at least one solar panel at two opposing ends thereof, such that a vertical movement of said at least one fluid-holding container exerts pulling forces on at least one selected from a group consisting of at least one first cable, at least one second cable and any combination thereof to result in pivoting movement of said at least one solar panel, (b) a crank-like tilt mechanism, (c) an arcuate slot tilt mechanism, comprising: at least one support frame in communication with said at least one solar panel, comprising one or more brackets having an arcuate guide slot wherein said at least one fluid-holding container is in communication with at least one guide pin fitted within said guide slot; such that said movement in said vertical dimension of at least one fluid-holding container is thus translated into angular movement of said support frame and said at least one solar panel, (d) a parallelogram with an underwater symmetrical frame, (e) a parallelogram with an underwater asymmetrical frame and push/pull rods; and any combination thereof.

7. The module of any of claims 1-5, further comprising a control unit in fluid communication with said at least one fluid-holding container, wherein the control unit is configured for selectively adjusting a fluid level within said at least one fluid-holding container further wherein said module further comprising at least one pipe connected between said control unit and said at least one fluid-holding container.

8. A system comprising:
a plurality of buoyant modules comprising each:

at least one base configured for being buoyantly supported within a body of water, and

at least one fluid-holding container sized and fitted for being connected with said at least one base, adapted for movement in the vertical dimension relative to said at least one base, wherein a vertical position of said at least one fluid-holding container relative to said at least one base is based, at least in part, on a fluid level in said at least one fluid-holding container;

at least one mount coupled to said at least one base in a sealing engagement against the egress of liquids into the interior of said at least one base and configured for pivotably mounting at least one solar panel thereon, wherein said mount comprises at least one opening sized and shaped to fit said at least one container and enable said movement in said vertical dimension,; and

at least one support frame, attached to the at least one mount and carrying said at least one solar panel;

wherein said at least one support frame is tiltable about a pivot point relative to said mount;

a framework comprising frame members configured for rigidly interconnecting at least two of said bases to at least one module from the plurality of buoyant modules in a specified arrangement; and

a control unit in fluid communication with each of said at least one fluid-holding container, wherein the control unit is configured for selectively adjusting a fluid level within said at least one fluid-holding container.

9. The system of claim 8, wherein said plurality of modules is arranged in a grid array field comprising at least one row and at least one column.

10. The system of any of claims 8-9, wherein said at least one fluid-holding container is sized and fitted for being received within said space.

11. The system of any of claims 8-10, wherein said at least one base comprises at least two hulls arranged in a spaced-apart position, wherein said hulls are rigidly interconnected to one another, and wherein said space is disposed therebetween said hulls; further wherein said hulls are made of at least one selected from a group consisting of solid, at least partially hollow, entirely hollow hulls and any combination thereof.

12. The system of any one of claims 8-11, wherein at least one of (a) base is at least partially filled with a ballast comprising at least one selected from a group consisting of liquid, solid and any combination thereof; (b) said base is in fluid communication with said body of water; (c) any combination thereof.

13. The system of claim 8, wherein said at least one base further comprises a tilt mechanism configured for translating said movement in said vertical dimension of said at least one fluid-holding container into said pivotable motion of said at least one solar panel about said pivot point; further wherein said tilt mechanism is configured for tilting said at least one solar panel between 25° and 75° to either side relative to the horizontal; further wherein said tilt mechanism is configured such that a center of gravity of said solar panel is located below or on said pivot point.

14. The system of claim 13, wherein said tilt mechanism comprises at least one mechanism selected from a group consisting of (a) a cable-and-pully tilt mechanism comprising: (i) at least one first cable coupled to the upper portion of said at least one fluid-holding container; (ii) at least one second cable coupled to the bottom portion of said at least one fluid-holding container; said at least one first cable and said at least one second cable are coupled to said at least one solar panel at two opposing ends thereof, such that said vertical movement of said at least one fluid-holding container exerts pulling forces on at least one selected from a group consisting of at least one first cable, at least one second cable and any combination thereof to result in pivoting movement of said at least one solar panel; (b) a crank-like tilt mechanism, (c) an arcuate slot tilt mechanism, comprising: at least one support frame in communication with said at least one solar panel, comprising one or more brackets having an arcuate guide slot wherein said at least one fluid-holding container is in communication with at least one guide pin fitted within said guide slot; such that said movement in said vertical dimension of at least one fluid-holding container is thus translated into angular movement of said support frame and said at least one solar panel; (d) a parallelogram with an underwater symmetrical frame, (e) a parallelogram with an underwater asymmetrical frame and push/pull rods and any combination thereof.

15. The system of any of claims 8-14, further comprising a control unit in fluid communication with said at least one fluid-holding container, wherein the control unit is configured for selectively adjusting a fluid level within said at least one fluid-holding container;

and wherein said module further comprising at least one pipe connected between said control unit and said at least one fluid-holding container.

16. The system of claim 12, wherein at least one of (a) said at least one solar panel is further configured for tilting in unison; (b) said framework further comprises one or more lines configured for mooring said system; (c) said one or more lines are further configured for facilitating adjustment of an azimuth angle of said system; (d) said system additionally comprising at least one pump in a closed fluid filling/emptying system, wherein fluid may be transferred from said at least one fluid-holding container to another; and (e) any combination thereof.

17. The system of claim 8, additionally comprising at least one selected from a group consisting of (a) at least one line extending outwardly from said framework to reach at least one selected from a group consisting onshore anchor points, a mooring buoy, mooring and anchoring system and any combination thereof; b) at least one horizontal ‘yo-yo’-like mooring and anchoring arrangement, comprising two or more lines wrap around said framework in opposing directions, so as to facilitate rotational positioning of said framework, such that, when rotational force applied to said framework will result in loosening at least one of said two or more lines while building tension in a second line; and (c) any combination thereof.

18. The system of claim 8, wherein a speed of a vertical movement, considering a changing weight of said at least one fluid-holding container, is depicted by the following equation:

$$v_v = \frac{\Delta Z}{t} = \frac{\Delta Z}{\left(\Delta V - \frac{\Delta M}{\rho_w}\right) / \text{FlowRate}}$$

$$= \frac{Z_2 - Z_1}{\left(V_2 - V_1 - \frac{M_2 - M_1}{\rho_w}\right) / \text{FlowRate}} \left[\frac{\text{cm}}{\left(\text{cm}^3 - \frac{\text{kg}}{\text{kg/cm}^3}\right) / \frac{\text{cm}^3}{\text{sec}}} \right]$$

where M1, M2 are the masses of the portions of said at least one fluid-holding container above fluid level, at the first location point 1 and the second location point 2, and pw is the density of the fluid.

19. The system of claim 8, additionally comprising at least one force dampening mechanism, comprising at least one additional container, said at least one additional container is coupled to said framework, said at least one additional container comprises one or more

apertures, configured to provide fluid communication between said at least one additional container and the body of water.

20. A method comprising:

- (a) providing the system according to any one of claims 8-19;
- (b) rigidly interconnecting at least two bases of said at least one modules in a specified arrangement;
- (c) fluidly connecting said control unit with said at least fluid-holding container, wherein the control unit is configured for selectively adjusting a fluid level within said at least one fluid-holding container; and
- (d) deploying said system in said body of water.