

FLOATING STRUCTURE FOR PHOTOVOLTAIC SYSTEM

[0001] The present disclosure relates to a floating structure for photovoltaic panels. More particularly, the present disclosure relates to floating structures for photovoltaic panels which may be linked together to form a larger floating structure.

BACKGROUND

[0002] The use of photovoltaic (PV) panels as a means of electricity generation is growing in popularity. Such panels can provide a way of harnessing renewable solar energy, thereby reducing the carbon footprint when compared with conventional electricity production means such as the combustion of coal.

[0003] PV panels, arranged into a PV array, require a significant area on which to be arranged and directed towards the sun. PV arrays are usually installed on land, but may also be installed on water.

SUMMARY

[0004] Examples of preferred aspects and embodiments of the invention are as set out in the accompanying independent and dependent claims.

[0005] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

[0006] In a first aspect of the disclosed technology, there is provided a photovoltaic cell assembly, comprising: a photovoltaic module; a rigid frame comprising an upright section and a sloped section, wherein the rigid frame is arranged to support the photovoltaic module; and a modular float connected to the rigid frame.

[0007] Optionally, the modular float comprises a silica alumina composite.

[0008] Optionally, the frame comprises a plurality of upright sections arranged to support the photovoltaic module vertically above the modular float.

[0009] Optionally, the photovoltaic module is supported by the rigid frame at an angle of between 5 degrees to 35 degrees with respect to the horizontal.

[0010] Optionally, the modular float is buoyant on fresh water and/or seawater.

[0011] Optionally, at least a portion of the modular float is in contact with solid terrain.

[0012] Optionally, the rigid frame allows the free movement of air through a frame structure of the rigid frame.

[0013] Optionally, the photovoltaic module comprises one or more of: a mono facial module; a dual glass module; a mono n-type module; a mono Passivated Emitter and Rear Contact (PERC) module; a bifacial module; a poly module; a Copper Indium Gallium Selenide (CIGS) module; an Intermediate Bus Converter (IBC) module; and/or a Cadmium Telluride (CdTe) module.

- [0014] Optionally, the photovoltaic module is operable to accommodate a power rating less than or equal to 600 Wp.
- [0015] Optionally, the module float has an approximate length of 2 metres; an approximate width of 0.6 metres; and/or an approximate height of 0.6 metres.
- [0016] Optionally, the module float comprises three lower sections.
- [0017] Optionally, each lower section has an approximate length of 0.4 metres.
- [0018] Optionally, there is further provided a photovoltaic (PV) inverter.
- [0019] Optionally, there is further provided a measurement tool operable to calculate a stress and/or strain applied to the rigid frame.
- [0020] Optionally, there is further provided a substation operable to perform at 2 MVa.
- [0021] Optionally, there is further provided one or more breakaway pontoons arranged to attenuate the impact of wave motion on the modular float.
- [0022] Optionally, there is further provided one or more of: a dead weight anchor; a ballast anchor; and/or a pile anchor.
- [0023] Optionally, the module float is operable to link to one or more other modular floats.
- [0024] Optionally, there is further provided one or more connector floats linked to the modular float.
- [0025] Optionally, the modular float comprises one or more integrated mooring shackles.
- [0026] According to a further aspect, there is provided a pontoon arrangement, comprising: a plurality of photovoltaic modules; a plurality of rigid frames each comprising an upright section and a sloped section, wherein each rigid frame is arranged to support at least one photovoltaic module; and a plurality of modular floats each connected to at least one rigid frame, wherein each of the plurality of modular floats is connected to at least one other of the plurality of modular floats and/or one or more connector floats to form a pontoon.
- [0027] Optionally, the plurality of modular floats and/or one or more connector floats are arranged in an alternating layout.
- [0028] Optionally, there is further provided a maintenance walkway.
- [0029] It will also be apparent to anyone of ordinary skill in the art, that some of the preferred features indicated above as preferable in the context of one of the aspects of the disclosed technology indicated may replace one or more preferred features of other ones of the preferred aspects of the disclosed technology. Such apparent combinations are not explicitly listed above under each such possible additional aspect for the sake of conciseness.
- [0030] Other examples will become apparent from the following detailed description, which, when taken in conjunction with the drawings, illustrate by way of example the principles of the disclosed technology.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0031] Figure 1A shows a floating photovoltaic arrangement in a freshwater environment;
- [0032] Figure 1B shows a floating photovoltaic arrangement in a marine environment;
- [0033] Figure 1C shows a floating photovoltaic arrangement in land and flood prone environments;
- [0034] Figures 2A-C show exemplary control arrangements for each of the environments of Figures 1A-C respectively;
- [0035] Figure 3 shows a series of photovoltaic modules from different suppliers which may be used in conjunction with the arrangement as disclosed herein;
- [0036] Figures 4A-4E show a series of photovoltaic modules of different form factors which may be used in conjunction with the arrangement as disclosed herein;
- [0037] Figure 5 shows an exemplary modular float;
- [0038] Figures 6A and 6B show different views of modular blocks using two connector floats;
- [0039] Figure 7 shows an example modular inverter block;
- [0040] Figures 8A and 8B show different cross sectional views of an arrangement as disclosed herein;
- [0041] Figures 9A and 9B show different views of modular blocks using a plurality of breakwater pontoons;
- [0042] Figure 10 shows an exemplary anchoring arrangement;
- [0043] Figures 11A and 11B show exemplary frame structures; and
- [0044] Figures 12A and 12B show different cross sectional views of an arrangement as disclosed herein.
- [0045] The accompanying drawings illustrate various examples. The skilled person will appreciate that the illustrated element boundaries (e.g., boxes, groups of boxes, or other shapes) in the drawings represent one example of the boundaries. It may be that in some examples, one element may be designed as multiple elements or that multiple elements may be designed as one element.

DETAILED DESCRIPTION

- [0001] Figure 1A shows a floating photovoltaic array in a freshwater environment. In this Figure, there are provided two modular floats 100. Between these modular floats 100 are arranged two photovoltaic modules 105, optionally in the form of photovoltaic panels. Although two modular floats 100 and two photovoltaic modules 105 are represented in this Figure, it is appreciated that one or more modular floats 100 and/or photovoltaic modules 105 may be used. The photovoltaic modules 105 are supported by a rigid frame 110, which supports the photovoltaic modules 105 vertically away from and above the modular floats 100. The arrangement of this Figure may be considered most suitable for

freshwater environments 115, such as reservoirs, lakes, and hydro dams. In these environments, it is anticipated that the wave height will not exceed 0.5 metres, and the water depth will have a range of less than or equal to 30 metres. The arrangement of this Figure may be constructed to withstand a maximum windspeed of up to 50 metres per second, but it is appreciated that similar arrangements are possible to withstand a greater water depth and/or wave height and/or maximum windspeed.

[0002] Figure 1B shows a floating photovoltaic arrangement in a marine environment. In this Figure, as in relation to Figure 1A, there are provided two modular floats 100 and between these modular floats 100 are arranged two photovoltaic modules 105, optionally in the form of photovoltaic panels. As in relation to Figure 1A, although two modular floats 100 and two photovoltaic modules 105 are represented, it is appreciated that one or more modular floats 100 and/or photovoltaic modules 105 may be used. The photovoltaic modules 105 are also supported by a rigid frame 110, which supports the photovoltaic modules 105 vertically away from and above the modular floats 100. However, in this example, the environment anticipated for this floating photovoltaic arrangement is a marine environment. This may be in a coastal water environment 120, including either nearshore or offshore. In such an environment, the arrangement may be constructed to withstand a wave height of up to 2 metres, and a water depth of up to 100 metres. The arrangement of this Figure may be constructed to withstand a maximum windspeed of up to 65 metres per second, but it is appreciated that similar arrangements are possible to withstand a greater water depth and/or wave height and/or maximum windspeed.

[0003] Figure 1C shows a floating photovoltaic arrangement in land and flood prone environments. As in relation to Figures 1A and 1B, there are provided two modular floats 100 and between these modular floats 100 are arranged two photovoltaic modules 105, optionally in the form of photovoltaic panels. As in relation to Figures 1A and 1B, although two modular floats 100 and two photovoltaic modules 105 are represented, it is appreciated that one or more modular floats 100 and/or photovoltaic modules 105 may be used. The photovoltaic modules 105 are also supported by a rigid frame 110, which supports the photovoltaic modules 105 vertically away from and above the modular floats 100. However, in this example, the environment anticipated for this photovoltaic arrangement is a land environment which may be prone to flooding, for example as part of a ground mount in a flood prone area, a portable arrangement, and/or a hydro dam. Unlike Figures 1A and 1B, at least one of the modular floats 100 may be placed directly on solid land 125, while maintaining structural integrity of the arrangement as a whole if a flood 130 occurs or water is otherwise introduced to the arrangement. In such an environment, the arrangement may be constructed to withstand a maximum windspeed of

up to 50 metres per second, but it is appreciated that similar arrangements are possible to withstand a greater maximum windspeed.

[0004] Figures 2A-C show exemplary control arrangements for each of the environments of Figures 1A-C respectively. In Figure 2A, there is represented a series of exemplary control options which may be used in line with a photovoltaic cell assembly constructed for freshwater use, represented as feature 205. There is provided in this example a plurality of modular floats 210 connected by connector floats 215. This arrangement may be constructed to withstand a wave height of up to 0.5 metres, and a maximum windspeed of up to 45 metres per second. Freshwater arrangement 205 may use mono facial or dual glass photovoltaic modules 220 as the photovoltaic modules of choice, operable to provide a power range of 380 Watt-Peak (W_p) to 605 W_p . Freshwater arrangement 205 may further comprise a photovoltaic medium voltage (MV) solution 225. This photovoltaic medium voltage (MV) solution 225 may comprise a photovoltaic inverter, a transformer, and M V switchgear. In some embodiments, this arrangement is operable to produce 100-250 kW_p or 3-7 MW_p depending on the type of inverter used. For example, a string inverter may provide the lower range, while a central inverter may provide the higher range. The freshwater arrangement 205 may be monitored remotely as represented in feature 230. This monitoring may be performed by a user, reviewing a range of data provided remotely from the freshwater arrangement 205. Many different analytic and software-based tools may be used for said monitoring, for example a power plant controller (PPC) in combination with a cloud server and predictive analytics. A PPC may comprise a programmable logic controller (PLC) that sets all the algorithms and key grid control settings of the inverters to meet a local grid code compliance and also to optimise the performance of the PV plant by the developer if they have the engineering capability. It can also manage and optimise of the technologies connected to the power plant such as energy storage and wind as a hybrid plant. The monitoring and control arrangement of feature 230 may provide useful data to an operations and maintenance division 235, as well as a cloud server and predictive analytics division 240.

[0005] In Figure 2B, there is represented a series of exemplary control options which may be used in line with a photovoltaic cell assembly constructed for use in a marine environment, represented as feature 250. There is provided in this example a plurality of modular floats 210 connected by connector floats 215. This arrangement may be constructed to withstand a wave height of up to 2 metres, and a maximum windspeed of up to 60 metres per second. The marine arrangement 250 may use mono facial or dual glass photovoltaic modules 220 as the photovoltaic modules of choice, operable to provide a power range of 380 W_p to 605 W_p . Freshwater arrangement 205 may further comprise a photovoltaic medium voltage (MV) solution 225. This photovoltaic medium voltage (MV)

solution 225 may comprise a photovoltaic inverter, a transformer, and MV switchgear, all operable to produce a power output within a certain range. The marine environment arrangement 205 may be monitored remotely as represented in feature 230. This monitoring may be performed by a user, reviewing a range of data provided remotely from the marine environment arrangement 205. Many different analytic and software-based tools may be used for said monitoring, for example PPC in combination with a cloud server and predictive analytics. The monitoring and control arrangement of feature 230 may provide useful data to an operations and maintenance division 235, as well as a cloud server and predictive analytics division 240.

[0006] In Figure 2C, there is represented a series of exemplary control options which may be used in line with a photovoltaic cell assembly constructed for use in land and flood prone areas, represented as feature 260. There is provided in this example a plurality of modular floats 210 connected by connector floats 215. This arrangement may be constructed to withstand a water height as dependent on the design and physical local requirements, and a maximum windspeed of up to 60 metres per second. The arrangement 260 may use mono facial or dual glass photovoltaic modules 220 as the photovoltaic modules of choice, operable to provide a power range of 380 W_p to 605 W_p. Freshwater arrangement 205 may further comprise a photovoltaic medium voltage (MV) solution 225. This photovoltaic medium voltage (MV) solution 225 may comprise a photovoltaic inverter, a transformer, and MV switchgear, all operable to produce a power output within a certain range. The land and flood prone arrangement 205 may be monitored remotely as represented in feature 230. This monitoring may be performed by a user, reviewing a range of data provided remotely from the land and flood prone arrangement 205. Many different analytic and software-based tools may be used for said monitoring, for example PPC in combination with a cloud server and predictive analytics. The monitoring and control arrangement of feature 230 may provide useful data to an operations and maintenance division 235, as well as a cloud server and predictive analytics division 240.

[0007] The arrangements of Figures 2A-C may provide a minimum performance guarantee of 90% P50, using validated equipment, validated plant design, an operations and maintenance (O&M) service, and an independent energy assessment. The arrangements of Figures 2A-C may further provide reduced fouling to the environment, resistance to corrosion, and a means of anchoring and/or mooring each arrangement to its predetermined location. Meteorological station sensors local or remote from each arrangement may be used to detect relevant weather conditions so that appropriate steps may be taken.

[0008] Figure 3 shows a series of photovoltaic panels from different suppliers which may be used in conjunction with the arrangement as disclosed herein. Such panels may include, for example: a mono n-type module 305; a mono Passivated Emitter and Rear Contact (PERC) module 310; a bifacial module 315; a poly module 320; a Copper Indium Gallium Selenide (CIGS) module 325; an Intermediate Bus Converter (IBC) module 330; and/or a Cadmium Telluride (CdTe) module 335. Each module may provide relevant advantages to the specific arrangement in which they are deployed.

[0009] Figures 4A-4E show a series of photovoltaic panels of different form factors which may be used in conjunction with the arrangement as disclosed herein. These photovoltaic modules may comprise a range of different form factors, and power ratings less than or equal to 600 W_p. However, it is understood that any power rating may potentially be developed by module manufacturers. The form factors may include, for example: n-type MF TR 78M 10BB 585 W_p (panel 405); BiFi n-type MF TR 9BB 470 W_p (panel 410); n-type MF TR 9BB 470 W_p (panel 415); a p-type BiFi dual glass MF TR 9BB 505 W_p (panel 420); and/or a p-type MF frameless dual glass 5BB 370 W_p (panel 425). Optionally, the or each panel, either individually or in combination, may be of approximate dimensions 2 metres by 1 metre.

[0010] Figure 5 shows an exemplary modular float. The modular float 505 of this example is an elongated rectangular shape, formed from a lightweight silica alumina composite material, with approximate dimensions 2 metres by 0.6 metres by 0.6 metres. The density of the silica alumina composite material used is approximately 500kg/m³. The weight of the modular float 505 is approximately 105 kg, and the buoyancy is 6,475 N.

[0011] The modular float 505 of this example comprises three holes bored through the modular float 505. There is one larger hole 510 with a diameter of 0.08 metres situated across the modular float 505, and two smaller holes 515 with diameters 0.06 metres situated longitudinally along the modular float 505. The main body of the modular float 505 comprises three lower sections with a consistent diameter of 0.5 metres, but with differing lengths of 0.4 metres, 0.6 metres, and 0.4 metres. The longest of the three lower sections is situated between the two other lower sections. The two gaps formed between the three lower sections are each of 0.2 metres in length. Each of sides of the three lower sections may be tapered such that when in use the lower side is of reduced dimensions compared to an upper side.

[0012] Figures 6A and 6B show different views of modular blocks using two connector floats. There is shown in Figure 6A two modular floats 605, also referred to as “main floats”, joined together via a connector float 610. Each of the main floats 605 and connector float 610 are linked to a float structure 615 comprising a plurality of beams. The float structure 615 supports a module support structure 620, comprising one or more

braces across the beams of the float structure 615 and optionally one or more cross braces 625. The float structure 615, the module support structure 620 and the optionally one or more cross braces 625 may be jointly referred to as a “rigid frame” and used to support the one or more photovoltaic cells. The distal end of the float structure 615 is then connected to another two main floats 605, joined together via a connector float 610. The rigid frame provides a more robust and longer lasting component compared to conventional High Density Poly Ethylene (HDPE) plastic, and provides 10-16 times more tensile strength when compared with Aluminium alloy or Steel grade. The rigid frame may be made of cold rolled metal such as steel, or galvanised magnesium alloy. The present arrangement may further provide an increased maximum wind load that can be safely applied to the rigid frame.

[0013] Zinc, Aluminium and Magnesium Alloy coatings that fall within ASTM A1046/A1046M Type 1, such as “ZAM” (a coined name applied to the hot-dipped zinc-aluminium-magnesium-alloy-coated steel sheets) have been shown to outperform galvanized coatings in corrosion resistance by 10 to 20 times. The chemistry of 6% Aluminium and 3% Magnesium may be at least part of the reason for the properties displayed. The ZAM material has a harder coating layer than both hot-dipped galvanized steel and hot-dipped zinc/aluminium alloy coated steel. This provides the advantages of greater resistance to damage in applications subject to repeated wear, and greater resistance to damage during transport and installation, ultimately providing an approximately four times greater scratch load when tested with a needle of radius 0.05 mm.

[0014] The rigid frame may further comprise a measurement tool operable to calculate a stress and/or strain applied to the rigid frame, placed on the metal support structure directly connecting two or more floats.

[0015] Figure 6B shows a view of the arrangement of Figure 6A, further comprising photovoltaic modules 640. The photovoltaic modules used may be, for example, one or more of those referenced herein, either individually or in combination.

[0016] Figure 7 shows an example modular inverter block. In this Figure, there is shown a series of photovoltaic cell assemblies 705 linked together to form a larger pontoon 710. The pontoon 710 of this example comprises two maintenance walkways 715, which can allow for maintenance personnel to perform the necessary checks, repairs, and replacements in order to keep the apparatus functional or for the purpose of upgrades. The pontoon may also comprise one or more photovoltaic inverters 720, and/or a 2 MVA substation 725. The substation 725 may be operable to perform at a lower or higher voltage if so designed.

[0017] Figures 8A and 8B show different cross sectional views of an arrangement as disclosed herein. In Figure 8A, there is shown a first cross sectional view comprising a plurality of modular floats 805 connected via a rigid frame 810. The modular floats 805 are floating on liquid water 820, for example in the form of a reservoir. The rigid frame 810 comprises at least one upright section and at least one sloped section, arranged to support a set of photovoltaic modules 815 vertically elevated away from the water 820 surface and the modular floats 805. By raising the photovoltaic modules 815 vertically away from the water 820 surface and the modular floats 805, increased airflow may occur below and above each of the photovoltaic modules 815. The forces on the rigid frame 810 applied, for example, as a result of the weight of the photovoltaic modules 815, are also removed from the modular floats 805 and isolated within the frame itself. This reduces wear and tear on the voltaic modules 815, as well as improving ventilation and airflow around the photovoltaic modules 815 resulting in a higher temperature coefficient (U_c) and an overall increase in energy yield. In some cases, this increase in energy yield may be up to 2%-7% compared to current market floating systems.

[0018] In Figure 8B, a similar arrangement as that in Figure 8A is shown but from a different viewing perspective. From this angle, it may be seen that the modular floats 805 may be connected either directly to each other, or through the use of connector floats 830. Connector floats 830 may provide further stability and rigidity to the arrangement as a whole, helping prolong the useful life of each photovoltaic cell assembly.

[0019] Figures 9A and 9B show different views of modular blocks using a plurality of breakwater pontoons. In these figures, there is shown a series of modular floats 905 connected to other modular floats 905 and/or connector floats. Each of the modular floats 905 and/or connector floats are linked to a float structure 915 comprising a plurality of beams. The float structure 915 supports a module support structure 920, comprising one or more braces across the beams of the float structure 915 and optionally one or more cross braces 925. The distal end of the float structure 915 is then connected to another set of modular floats 905. However, in this embodiment, a further set of modular floats 905 are linked to the first set of modular floats 905 to form a larger assembly. The further set of modular floats 905 are also linked to a float structure 915 comprising a plurality of beams. The float structure 915 supports a module support structure 920, comprising one or more braces across the beams of the float structure 915 and optionally one or more cross braces 925. This further set of modular floats 905 are then linked to one or more breakwater pontoons 940, which help attenuate the waves and reduce the dynamic loads of the rest of the photovoltaic cell assemblies. The or each breakwater pontoon 940 and/or modular floats 905 may be equipped with integrated mooring shackles. One or more of the modular floats 905 may be linked to one or more dead weight or ballast anchors 945.

One or more of the breakwater pontoons 940, for example the breakwater pontoon 940 nearest the perimeter of the overall assembly, may be linked to one or more pile anchors 950. Figure 9B shows a similar arrangement, but further showing the placement of a set of photovoltaic modules 965 being supported by the float structure 915 and module support structure 920, optionally comprising one or more cross braces 925.

[0020] Figure 10 shows an exemplary anchoring arrangement. In this Figure, there are shown two breakwater pontoons 1005 tethered to a pile anchor 1010 such that tensile forces are transmitted along the mooring lines 1020 in reaction to the wave loads on the breakwater pontoons 1005. Mooring lines 1020 are used to tether one or more modular floats 1015 to dead weight or ballast anchors 1025 beneath the surface of the water 1030. One or more of the modular floats 1015, for example the floats around the perimeter of the overall arrangement, may comprise integrated mooring shackles 1035. These integrated mooring shackles 1035 connect to the mooring line 1020 and help transmit the loads of the structure of the photovoltaic array onto the anchor 1025. Between the modular floats 1015 is provided a rigid frame 1045 supporting one or more photovoltaic modules 1040. The rigid frame 1045 is again arranged to support the photovoltaic modules 1040 vertically elevated away from the water 1030 surface and the modular floats 1015. Tensile forces may be transmitted along the rigid frame 1045 induced by the wind loads.

[0021] Figures 11A and 11B show exemplary frame structures. In Figure 11A, there are shown four modular floats 1105, surrounding a main support structure 1115 with four sides and a central beam. In this embodiment, each modular float 1105 has dimensions 2 metres by 0.6 metres by 0.5 metres. The main support structure 1115 works alongside a module support structure 1120, comprising one or more braces and optionally one or more cross braces 1125. The main support structure 1115, the module support structure 1120 and the optionally one or more cross braces 1125 may be jointly referred to as a “rigid frame” and used to support the one or more photovoltaic cells. Figure 11B shows an alternative arrangement, in which a different main support structure 1130 is used to connect two maintenance walkways 1135 via three beams, wherein each of the maintenance walkways 1135 has dimensions 6 metres by 0.5 metres by 0.03 metres.

[0022] Figure 12A shows a cross sectional view of four modular floats 1205 floating in water 1210, and supporting an array of 12 photovoltaic modules 1215. Each photovoltaic module array 1215 comprises six cells, giving a total of 72 cells. Each photovoltaic module array 1215 of this example has dimensions 1980 mm by 998 mm by 35 mm. The photovoltaic modules 1215 may be supported by Z steel purlins 1220 of dimensions 50 mm by 75 mm by 50 mm, 2 mm THK. For wiring, a DC solar cable tray 1225 may be used of dimensions 60 mm by 150 mm by 60 mm, made of stainless steel. The maintenance

walkway 1230 of this embodiment has dimensions 6000 mm by 500 mm by 40 mm, and is used alongside a structure connector 1240 of dimensions 100 mm by 80 mm by 10 mm. The structure connector 1230 may be made of aluminium alloy 6061,. A main support 1245 extends vertically from each modular float 1205, formed from 100 mm diameter HDG steel. The modular float 1205 itself is formed from a low density concrete composite.

[0023] A different cross sectional view is shown in Figure 12B, which shows a clearer view of a rigid frame 1250. In this embodiment, the rigid frame is formed from a plurality of upright sections, horizontal sections, and sloped sections. Space density may be improved using the particular cross sectional arrangement of beams as shown in Figure 12B. The frame 1215 may be adapted such that the angle of the photovoltaic modules 1215 with respect to the horizontal is adjustable between 5 degrees and 35 degrees.

[0024] The description is made for the purpose of illustrating the general principles of the present technology and is not meant to limit the inventive concepts claimed herein. As will be apparent to anyone of ordinary skill in the art, one or more or all of the particular features described herein in the context of one embodiment are also present in some other embodiment(s) and/or can be used in combination with other described features in various possible combinations and permutations in some other

[0025] Any reference to 'an' item refers to one or more of those items. The term 'comprising' is used herein to mean including the method blocks or elements identified, but that such blocks or elements do not comprise an exclusive list and an apparatus may contain additional blocks or elements and a method may contain additional operations or elements. Furthermore, the blocks, elements and operations are themselves not impliedly closed.

[0026] The steps of the methods described herein may be carried out in any suitable order, or simultaneously where appropriate. The arrows between boxes in the figures show one example sequence of method steps but are not intended to exclude other sequences or the performance of multiple steps in parallel. Additionally, individual blocks may be deleted from any of the methods without departing from the spirit and scope of the subject matter described herein. Aspects of any of the examples described above may be combined with aspects of any of the other examples described to form further examples without losing the effect sought. Where elements of the figures are shown connected by arrows, it will be appreciated that these arrows show just one example flow of communications (including data and control messages) between elements. The flow between elements may be in either direction or in both directions.

[0027] Where the description has explicitly disclosed in isolation some individual features, any apparent combination of two or more such features is considered also to be disclosed,

to the extent that such features or combinations are apparent and capable of being carried out based on the present specification as a whole in the light of the common general knowledge of a person skilled in the art, irrespective of whether such features or combinations of features solve any problems disclosed herein. In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.

CLAIMS

1. A photovoltaic cell assembly, comprising:
 - a photovoltaic module;
 - a rigid frame comprising an upright section and a sloped section, wherein the rigid frame is arranged to support the photovoltaic module; and
 - a modular float connected to the rigid frame.
2. The assembly of claim 1, wherein the modular float comprises a silica alumina composite.
3. The assembly of any preceding claim, wherein the frame comprises a plurality of upright sections arranged to support the photovoltaic module vertically above the modular float.
4. The assembly of any preceding claim, wherein the photovoltaic module is supported by the rigid frame at an angle of between 5 degrees to 35 degrees with respect to the horizontal.
5. The assembly of any preceding claim, wherein the modular float is buoyant on fresh water and/or seawater.
6. The assembly of any preceding claim, wherein at least a portion of the modular float is in contact with solid terrain.
7. The assembly of any preceding claim, wherein the rigid frame allows the free movement of air through a frame structure of the rigid frame.
8. The assembly of any preceding claim, wherein the photovoltaic module comprises one or more of: a mono facial module; a dual glass module; a mono n-type module; a mono Passivated Emitter and Rear Contact (PERC) module; a bifacial module; a poly module; a Copper Indium Gallium Selenide (CIGS) module; an Intermediate Bus Converter (IBC) module; and/or a Cadmium Telluride (CdTe) module.
9. The assembly of any preceding claim, wherein the photovoltaic module is operable to accommodate a power rating less than or equal to 600 W_p.
10. The assembly of any preceding claim, wherein the module float has an approximate length of 2 metres; an approximate width of 0.6 metres; and/or an approximate height of 0.6 metres.

11. The assembly of any preceding claim, wherein the module float comprises three lower sections.
12. The assembly of claim 11, wherein each lower section has an approximate length of 0.4 metres.
13. The assembly of any preceding claim, further comprising a photovoltaic (PV) inverter.
14. The assembly of any preceding claim, further comprising a measurement tool operable to calculate a stress and/or strain applied to the rigid frame.
15. The assembly of any preceding claim, further comprising a substation operable to perform at 2 MVa.
16. The assembly of any preceding claim, further comprising one or more breakaway pontoons arranged to attenuate the impact of wave motion on the modular float.
17. The assembly of any preceding claim, further comprising one or more of: a dead weight anchor; a ballast anchor; and/or a pile anchor.
18. The assembly of any preceding claim, wherein the module float is operable to link to one or more other modular floats.
19. The assembly of any preceding claim, further comprising one or more connector floats linked to the modular float.
20. The assembly of any preceding claim, wherein the modular float comprises one or more integrated mooring shackles.
21. The assembly of any preceding claim, comprising at least four (4) modular floats arranged to improve stability.
22. A pontoon arrangement, comprising:
 - a plurality of photovoltaic modules;
 - a plurality of rigid frames each comprising an upright section and a sloped section, wherein each rigid frame is arranged to support at least one photovoltaic module; and

a plurality of modular floats each connected to at least one rigid frame, wherein each of the plurality of modular floats is connected to at least one other of the plurality of modular floats and/or one or more connector floats to form a pontoon.

23. The pontoon of claim 22, wherein the plurality of modular floats and/or one or more connector floats are arranged in an alternating layout.
24. The pontoon of claim 22 or claim 23, further comprising a maintenance walkway.