assemble (such that assembly times and associated labor costs are reduced). As will be shown herein, the present system achieves these objectives by providing an inexpensive and lightweight system. The present system can be compacted when shipped and assembled relatively easily and inexpensively. In addition, the present system uses relatively fewer components than are normally found in floating solar PV arrays to support the PV modules.

[0007] Another common problem with floating solar PV arrays is that it can be difficult to access all of their components after they have been assembled and deployed out on the body of water. As will be shown, the present system has design features that permit easy operator access to the various parts of the array while the array is floating on the body of water.

[0008] Another problem with floating solar PV arrays is that they typically do not move their PV module orientation to track the movement of the sun. As will be shown, the present system includes optional mechanisms that can move the PV modules both by adjusting their angle of tilt to the horizon and also optionally by rotating the array on the water's surface to track the movement of the sun. As such, multi-axes tracking of the sun can be achieved using the present system.

Summary of the Invention:

[0009] In preferred embodiments, the present system includes a system for powering an accessory device with power generated on a floating solar photovoltaic (PV) array, comprising: a plurality of PV modules; a plurality of floating pontoons for supporting the PV modules above the water; an inverter for receiving DC power from the PV modules and converting the DC power to AC power, wherein the inverter has an AC power limit such that any power received above the AC Power limit would be clipped by the inverter; at least one powered accessory device; a power line running from the floating solar array to an on-shore grid; and an energy management power control system.

[0009a] According to a first aspect, there is provided a system for powering an accessory device with power generated on a floating solar photovoltaic (PV) array, including: (a) a plurality of PV modules; (b) a plurality of floating pontoons for supporting the PV modules above the water; (c) an inverter for receiving DC power from the PV modules and converting the DC power to AC power, wherein the inverter has an AC power limit such that any power received above the AC Power limit would be clipped by the inverter; (d) at least one powered accessory device; (e) a power line running from the floating solar array to an on-shore grid; and (f) an energy management power control system configured to send power that has been clipped by the inverter to the at least one powered accessory device, wherein the energy management power control system is configured to send power to the at least one powered accessory device by adjustably changing the amounts of power received from each of the following power sources over a period of time: power received from the PV modules that has been clipped by the inverter, power received from the PV modules that has not been clipped by the inverter, and power received from the on-shore grid.

[0009b] According to a second aspect, there is provided a system for powering an accessory device with power generated on a floating solar photovoltaic (PV) array, including: (a) a plurality of PV modules; (b) a plurality of floating pontoons for supporting the PV modules above the water; (c) an inverter for receiving DC power from the PV modules and converting the DC power to AC power, wherein the inverter has an AC power limit such that any power received above the AC Power limit would be clipped by the inverter; (d) at least one powered accessory device; (e) a power line running from the floating solar array to an on-shore grid; (f) an energy management power control system configured to send power that has been clipped by the inverter to the at least one powered accessory device; wherein the plurality of

floating pontoons comprise: a plurality of inflatable upper support pontoons with upper mounting hardware thereon and a plurality of inflatable lower support pontoons with lower mounting hardware thereon, wherein each solar photovoltaic module has an upper end that is connected to the mounting hardware on one of the inflatable upper support pontoons and a lower end that is connected to the mounting hardware on one of the inflatable lower support pontoons, and wherein the mounting hardware on the inflatable upper support pontoons is higher than the mounting hardware on the inflatable lower support pontoons to thereby hold each of the solar photovoltaic modules at an inclined angle; and (g) an air manifold system, comprising: at least one of an air source or an air compressor, and pneumatic tubing connecting the air source or air compressor to each of the plurality of inflatable support pontoons; pressure sensors for determining air pressures in the inflatable support pontoons; and an air manifold control system for controlling the air pressures in the inflatable support pontoons.

[0009c] According to a third aspect, there is provided a system for powering an accessory device with power generated on a floating solar photovoltaic (PV) array, including: (a) a plurality of PV modules; (b) a plurality of floating pontoons for supporting the PV modules above the water; (c) an inverter for receiving DC power from the PV modules and converting the DC power to AC power, wherein the inverter has an AC power limit such that any power received above the AC Power limit would be clipped by the inverter; (d) at least one powered accessory device; (e) a power line running from the floating solar array to an on-shore grid; (f) an energy management power control system configured to send power that has been clipped by the inverter to the at least one powered accessory device; wherein the plurality of floating pontoons comprise: a plurality of inflatable upper support pontoons with upper mounting hardware thereon and a plurality of inflatable lower support pontoons with lower mounting hardware thereon, wherein each solar photovoltaic module has an upper end that is connected to the mounting hardware on one of the inflatable upper support pontoons and a lower end that is connected to the mounting hardware on one of the inflatable lower support pontoons, and wherein the mounting hardware on the inflatable upper support pontoons is higher than the mounting hardware on the inflatable lower support pontoons to thereby hold each of the solar photovoltaic modules at an inclined angle; and wherein the inclined angle of each of the solar photovoltaic modules is adjusted by adjusting an inflation level in one of the inflatable upper support pontoons.

[0010] The energy management control system is configured to send power to at least one powered accessory device (which preferably includes a water remediation device, air compressor, mooring system or other device). The power sent to this accessory device includes power that has been clipped by the inverter. The advantage of this approach (i.e.: using inverter-clipped power to power the accessory device) is that it powers the accessory device with power that would otherwise be lost and not sent to shore. In optional embodiments, however, the power sent to the accessory device can also include power that has not been clipped by the inverter. This approach includes sending power to the accessory device that could otherwise have been sent from the array directly to the on-shore power grid. This approach could be beneficial for short periods of time when it is necessary to have the powered accessory device turned on (for example, during extended water remediation), but when the inverter-clipped power is not sufficient all by itself to power the water remediation device. The present energy management control system thus balances (and varies) these two different sources of power over time. For example, some of the non-clipped power could be sent from the PV modules to keep an aerator on late in the day when the array's power output is lower (such that inverter-clipped power alone would not be able to keep the aerator running). In optional preferred embodiments, the present energy management control system also is configured to receive power through a power line running from the floating solar array to the on-shore grid to send power to at least one powered accessory device. Again, this third

source of power can be balanced and controlled over time. As a result, the present energy management power control system is configured to send power to at least one powered accessory device by adjustably changing the amounts of power received from each of the following power sources over a period of time: (i) power received from the PV modules that has been clipped by the inverter, (ii) power received from the PV modules that has not been clipped by the inverter, and (iii) power received from the on-shore grid. True, three-way power balancing can be achieved.

[0011] In preferred embodiments, the powered water remediation accessory device is a water quality device, being one or more of an aerator, a diffuser, a sub-surface agitator, a sub-surface water circulator, or a water quality sensor. In other embodiments, the powered accessory device is an air compressor for inflating the plurality of pontoons. In yet other embodiments, the powered accessory device is a positional mooring device, a panel washer, or a bird removal system.

[0012] In various embodiments, the present floating solar PV array comprises: (a) a plurality of inflatable upper support pontoons with upper mounting hardware thereon; (b) a plurality of lower support pontoons with lower mounting hardware thereon; and (c) a plurality of solar photovoltaic modules, wherein each solar photovoltaic module has an upper end that is connected to the mounting hardware on one of the inflatable upper support pontoons and a lower end that is connected to the mounting hardware on one of the lower support pontoons. The mounting hardware on the inflatable upper support pontoons is higher (i.e.: farther from the water) than the mounting hardware on the lower support pontoons to thereby hold each of the solar photovoltaic modules at an inclined angle to the water below. In addition, the mounting hardware of the present system involves a minimum of parts. In one embodiment, only hooks or module mounting feet are used to attach the ends of the PV modules to each of the upper and lower support pontoons.

[0012a] According to a fourth aspect, there is provided a floating solar photovoltaic array, including: a plurality of inflatable upper support pontoons with upper mounting hardware thereon; a plurality of inflatable lower support pontoons with lower mounting hardware thereon; and a plurality of solar photovoltaic modules, wherein each solar photovoltaic module has an upper end that is connected to the mounting hardware on one of the inflatable upper support pontoons and a lower end that is connected to the mounting hardware on one of the inflatable lower support pontoons, wherein the mounting hardware on the inflatable upper support pontoons is higher than the mounting hardware on the inflatable lower support pontoons to thereby hold each of the solar photovoltaic modules at an inclined angle; and an air manifold system, including: at least one of an air source or an air compressor, and pneumatic tubing connecting the air source or air compressor to each of the plurality of inflatable support pontoons; pressure sensors for determining air pressures in the inflatable support pontoons; and an air manifold control system for controlling the air pressures in the inflatable support pontoons.

[0012b] According to a fifth aspect, there is provided a floating solar photovoltaic array, including: a plurality of inflatable upper support pontoons with upper mounting hardware thereon; a plurality of inflatable lower support pontoons with lower mounting hardware thereon; and a plurality of solar photovoltaic modules, wherein each solar photovoltaic module has an upper end that is connected to the mounting hardware on one of the inflatable upper support pontoons and a lower end that is connected to the mounting hardware on one of the inflatable lower support pontoons, wherein the mounting hardware on the inflatable upper support pontoons is higher than the mounting hardware on the inflatable lower support pontoons to thereby hold each of the solar photovoltaic modules at an inclined angle; and wherein the inclined angle of each of the solar photovoltaic modules is adjusted by adjusting

an inflation level in one of the inflatable upper support pontoons.

[0012c] According to a sixth aspect, there is provided a floating solar photovoltaic array, including: a plurality of inflatable upper support pontoons with upper mounting hardware thereon; a plurality of inflatable lower support pontoons with lower mounting hardware thereon; and a plurality of solar photovoltaic modules, wherein each solar photovoltaic module has an upper end that is connected to the mounting hardware on one of the inflatable upper support pontoons and a lower end that is connected to the mounting hardware on one of the inflatable lower support pontoons, wherein the mounting hardware on the inflatable upper support pontoons is higher than the mounting hardware on the inflatable lower support pontoons to thereby hold each of the solar photovoltaic modules at an inclined angle; and wherein the lower support pontoons have a flattened top surface functioning as a walkway.

[0012d] According to a seventh aspect, there is provided a floating solar photovoltaic array, including: a plurality of inflatable upper support pontoons with upper mounting hardware thereon; a plurality of inflatable lower support pontoons with lower mounting hardware thereon; and a plurality of solar photovoltaic modules, wherein each solar photovoltaic module has an upper end that is connected to the mounting hardware on one of the inflatable upper support pontoons and a lower end that is connected to the mounting hardware on one of the inflatable lower support pontoons, wherein the mounting hardware on the inflatable upper support pontoons is higher than the mounting hardware on the inflatable lower support pontoons to thereby hold each of the solar photovoltaic modules at an inclined angle; and wherein a center portion of each solar photovoltaic module is positioned directly above water with no mechanical structure positioned directly thereunder.

[0012e] According to an eighth aspect, there is provided a floating solar photovoltaic array, including: a plurality of inflatable upper support pontoons with upper mounting hardware thereon; a plurality of inflatable lower support pontoons with lower mounting hardware thereon; and a plurality of solar photovoltaic modules, wherein each solar photovoltaic module has an upper end that is connected to the mounting hardware on one of the inflatable upper support pontoons and a lower end that is connected to the mounting hardware on one of the inflatable lower support pontoons, wherein the mounting hardware on the inflatable upper support pontoons is higher than the mounting hardware on the inflatable lower support pontoons to thereby hold each of the solar photovoltaic modules at an inclined angle; and a powered accessory including at least one of an aerator, a diffuser, a sub-surface agitator, a sub-surface water circulator, a sub-surface positioning system, a water quality sensor; a panel washer, or a bird removal system, wherein the powered accessory is powered by the photovoltaic modules in the solar photovoltaic array.

[0013] The present system also comprises an air manifold system. As described herein, the air manifold system can include any air source. As such, the air source can include an air compressor or an air tank or a combination thereof. Pneumatic tubing is provided to connect the air source to each of the plurality of inflatable support pontoons. Pressure sensors are also preferably provided for determining air pressures in the inflatable support pontoons. An air manifold control system controls the air pressures in the inflatable support pontoons. Preferably, the entire air manifold system is powered by the photovoltaic modules in the solar photovoltaic array. As such, the present system can be fully self-contained in terms of sensing and maintaining its internal air pressures. This offers numerous benefits. For example, should air pressures fall in any of the support pontoons, the present system is able to detect the pressure drop and provide correction and re-inflate the support pontoons to within desired pressure ranges. A particularly unique advantage of the present self-contained pontoon inflation control system is that the pressures in the upper support pontoons can be changed to adjust the incident angle of the PV modules towards the sun. In addition, the upper support

pontoons can be partially deflated to “stow” the system for safety reasons if the system is struck by adverse weather conditions.

[0014] An important advantage of the present system of upper and lower pontoons supporting the solar PV modules is that they substantially reduce the physical shipping volume of components in the array. Specifically, since the upper pontoons are inflatable, they are lightweight and can ideally be collapsed and packed tightly together during shipping. In various embodiments, the lower pontoons may be inflatable as well, further reducing the shipping size and weight of the present system. In preferred embodiments, the upper support pontoons may simply be inflatable cylinders with mounting hardware attached directly thereto.

[0015] In preferred embodiments, the inclined angle of each of the solar photovoltaic modules can be adjusted by adjusting an inflation level in the inflatable upper support pontoons. This advantageously provides the ability to track the sun’s movement over the course of the day to optimize power generation in the array.

[0016] In preferred embodiments, the lower support pontoons may have a flattened top surface that functions as a walkway that supports the weight of an operator. This flattened top surface advantageously permits ease of access during both initial assembly on the water and for system maintenance thereafter.

[0017] In preferred embodiments, the upper and lower support pontoons hold each of the solar PV modules above the water such that the center portion of each solar PV module is suspended directly above the water with no mechanical structures positioned directly underneath. As such, the solar PV modules are each simply suspended above the water with the only mechanical connection between any of the inflatable upper support pontoons and any of the lower support pontoons being through the solar photovoltaic module itself. The advantage of this design is that it substantially reduces the total amount of system support hardware. In fact, the mounting hardware on each of the inflatable upper support pontoons can simply include a U-ring connector thermally welded or adhesively connected to the inflatable upper support pontoon. In contrast, existing floating solar arrays tend to require many more fastening components.

[0018] In preferred embodiments, the present system also includes a powered accessory which may be an aerator, a diffuser, a sub-surface agitator, a sub-surface water circulator, a sub-surface positioning/mooring system, a water quality sensor; a PV module panel washer, or even or a bird removal system, or some combination thereof. The advantage of aerators, diffusers, sub-surface agitators, sub-surface water circulators, and water quality sensors is that they can be used to improve water quality. The advantage of a sub-surface mooring system is that it can be used to keep the array at a preferred location, and to optionally rotate the array to track the movement of the sun across the sky. The advantages of panel washing or bird-removal systems are that they can be used to maximize power generation from the array. In all cases, these different powered accessories are preferably powered using inverter-clipped power from the PV modules in the array itself. As stated above, these various accessories may be completely powered by the array, or the array may power these accessories some of the time. The present energy management control system determines which power source(s) are used at which times and in what amounts. The energy management control system also adjusts these various energy sources over time under changing conditions. As such, the energy management control system can supply power generated by the PV modules in the array (including both inverter-clipped power and power that has not been clipped by the inverter) together with optional power sources including an on-board battery, or a power connection line to the on-shore grid, or both. In most preferred

embodiments, and during most of the time, the powered accessory can advantageously be powered by the output from the solar PV modules that has been clipped by an inverter. As such, the accessories can be powered from power that would otherwise be lost and not sent to shore.

[0019] A further advantage of the present system is that there is a wide variety of different configurations or layouts in which the system can be deployed. For example, the individual solar PV modules can be laid out in rows with all of the solar PV modules facing south. Alternatively, the solar PV modules can be laid out with alternating rows angled east and west. The individual solar PV modules can all be laid out in portrait orientation. Alternatively, however, the individual solar PV modules can all be laid out in landscape orientation.

[0020] In various preferred embodiments, the present solar PV array can have different numbers of upper and lower support pontoons in different configurations. For example, in various arrangements, each of the solar PV modules can have their own dedicated upper support pontoon. Alternatively, two or more solar PV modules can share the same upper support pontoon. In addition, although several solar PV modules can be mounted to the same lower support pontoon, the width of the present array can be extended by linking together more than one lower support pontoon.

Brief Description of the Drawings:

[0021] Fig. 1 is a perspective view of one embodiment of the present solar photovoltaic array.

[0022] Fig. 2A is a side elevation view of a section of an embodiment of the present solar photovoltaic array in a south-facing orientation.

[0023] Fig. 2B is a side elevation view of a section of an embodiment of the present solar photovoltaic array in an east-west south-facing orientation.

[0024] Fig. 3 is a simplified schematic perspective view of an array corresponding to Fig. 2A.

[0025] Fig. 4A is a side elevation view of an embodiment of the present solar PV array showing optional powered accessories including a surface aerator, a diffuser, sub-surface agitator, and a sub-surface water circulator.

[0026] Fig. 4B is a side elevation view of an embodiment of the present solar PV array showing an optional sub-surface mooring system.

[0027] Fig. 4C is a perspective view of the solar PV array of Fig. 1, showing a panel washer and a bird removal system.

[0028] Fig. 5 is an exemplary graph of array power generated over time showing the portion of inverter-clipped power directed to the powered accessory.

[0029] Fig. 6A is an exemplary graph showing inverter-clipped power sent to a powered accessory over a period of time.