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(54) **STRATOSPHERE TETHERED PHOTOVOLTAIC POWER PLATFORM**

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H01L 31/042 (2014.01)
H01L 31/04 (2014.01)

(52) **U.S. Cl.**
CPC . ***H02S 20/00*** (2013.01); ***B64B 1/50*** (2013.01); ***H02S 10/00*** (2013.01); *Y10S 136/292* (2013.01)
USPC **244/2**; 244/33; 136/292; 104/22

(58) **Field of Classification Search**
USPC 244/2, 3, 158.2, 30, 31, 33, 115, 116; 104/22; 136/292
See application file for complete search history.

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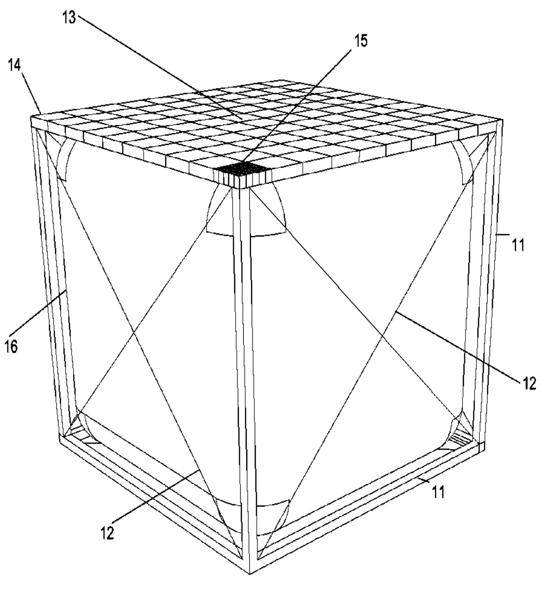
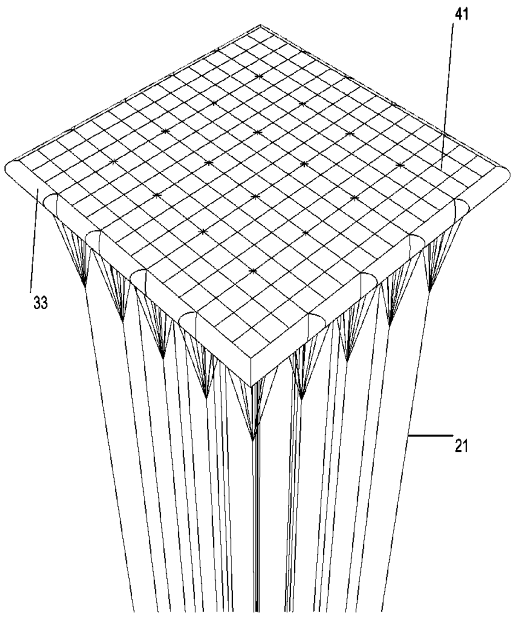
(57) **ABSTRACT**

The present invention is realized by apparatus and methods for placing a large utility scale photovoltaic array in the low stratosphere of earth's atmosphere at an altitude of about 20 km, above clouds, moisture, dust, and wind. This is accomplished using a large light-weight, rigid, buoyant structure to support the large photovoltaic array. Long, strong and light tethers connect the buoyant structure to the ground and hold it in position against wind forces. The electricity output from the photovoltaic array is then coupled to high voltage transmission lines which connect from the platform to the earth's surface. The electricity is then transmitted through the high voltage transmission lines to the earth's surface where it is connected to the electrical supply grid and provides lower cost, more reliable electricity.

18 Claims, 7 Drawing Sheets





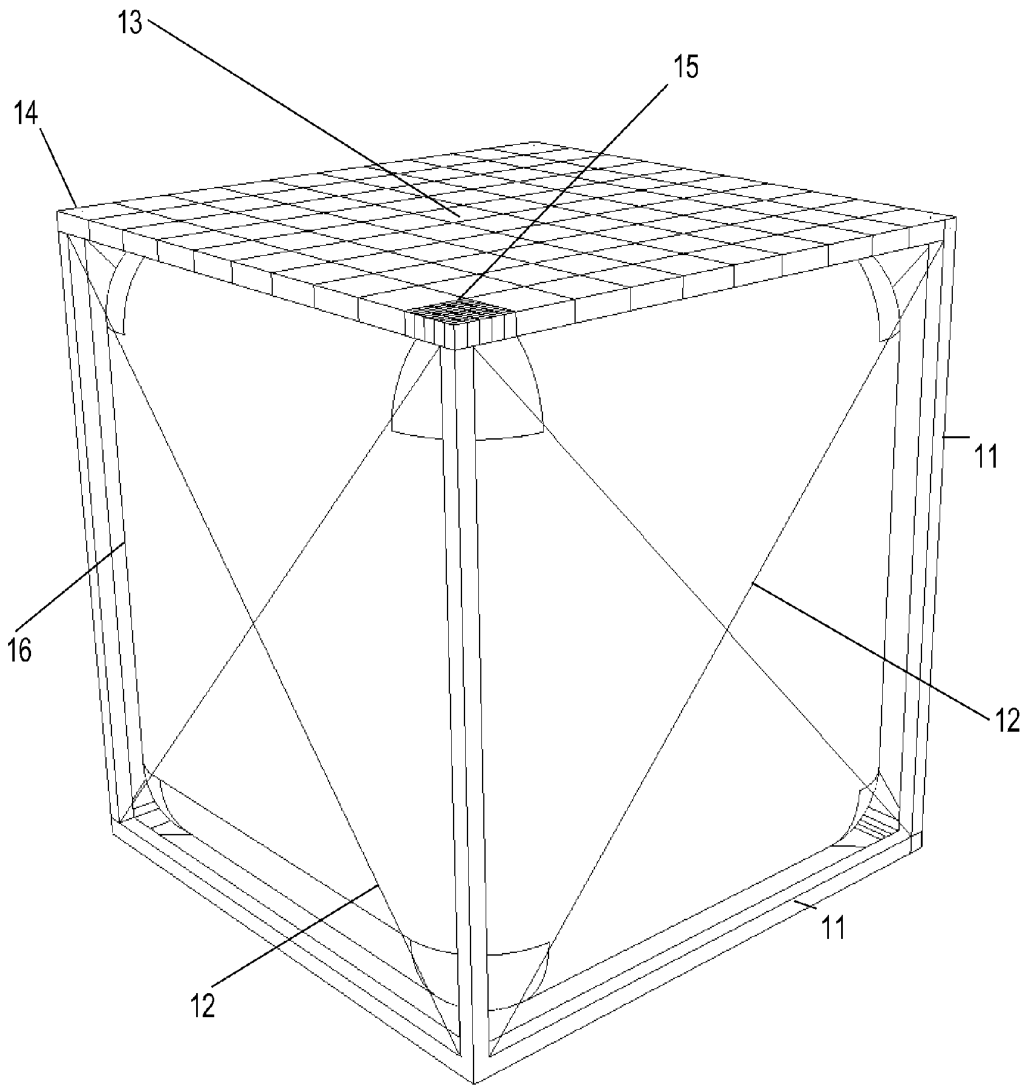


Fig. 1

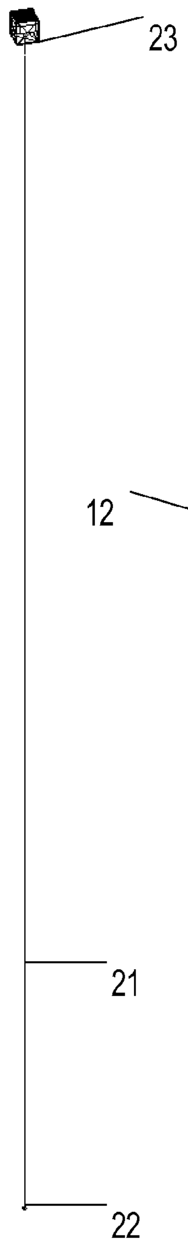


Fig. 2B

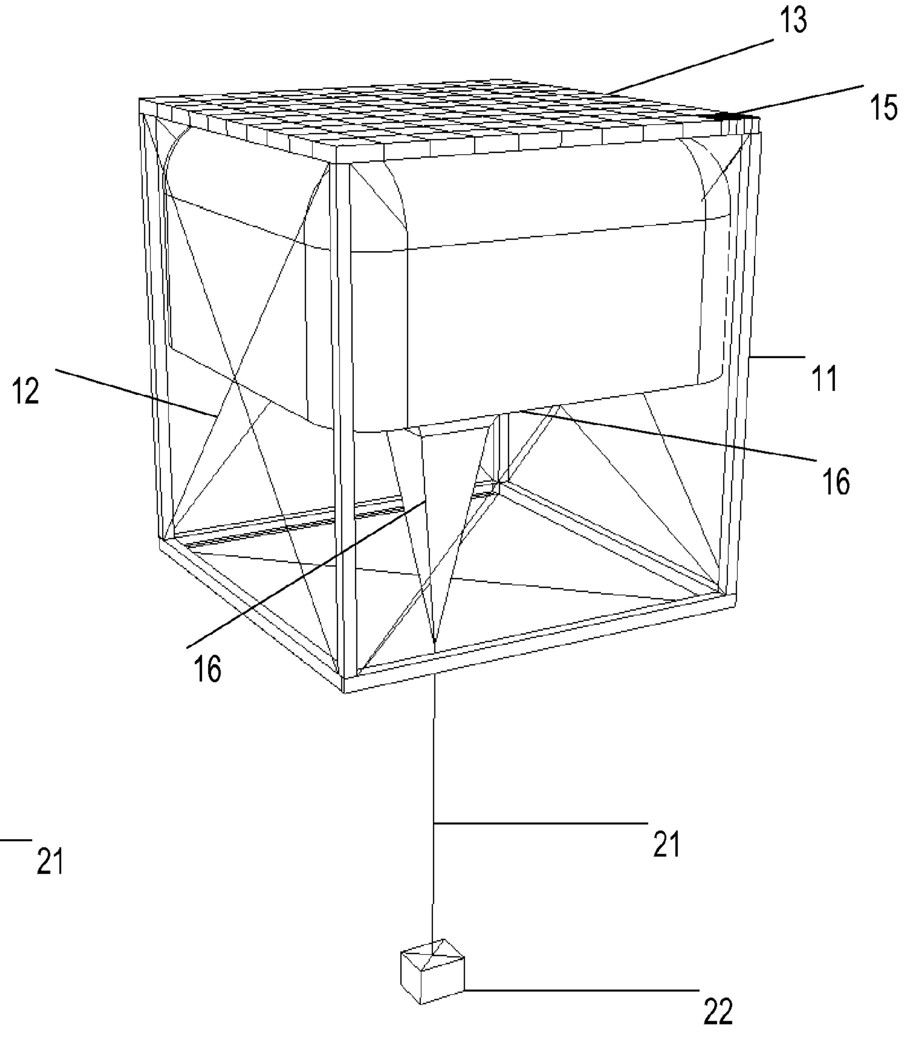


Fig. 2A

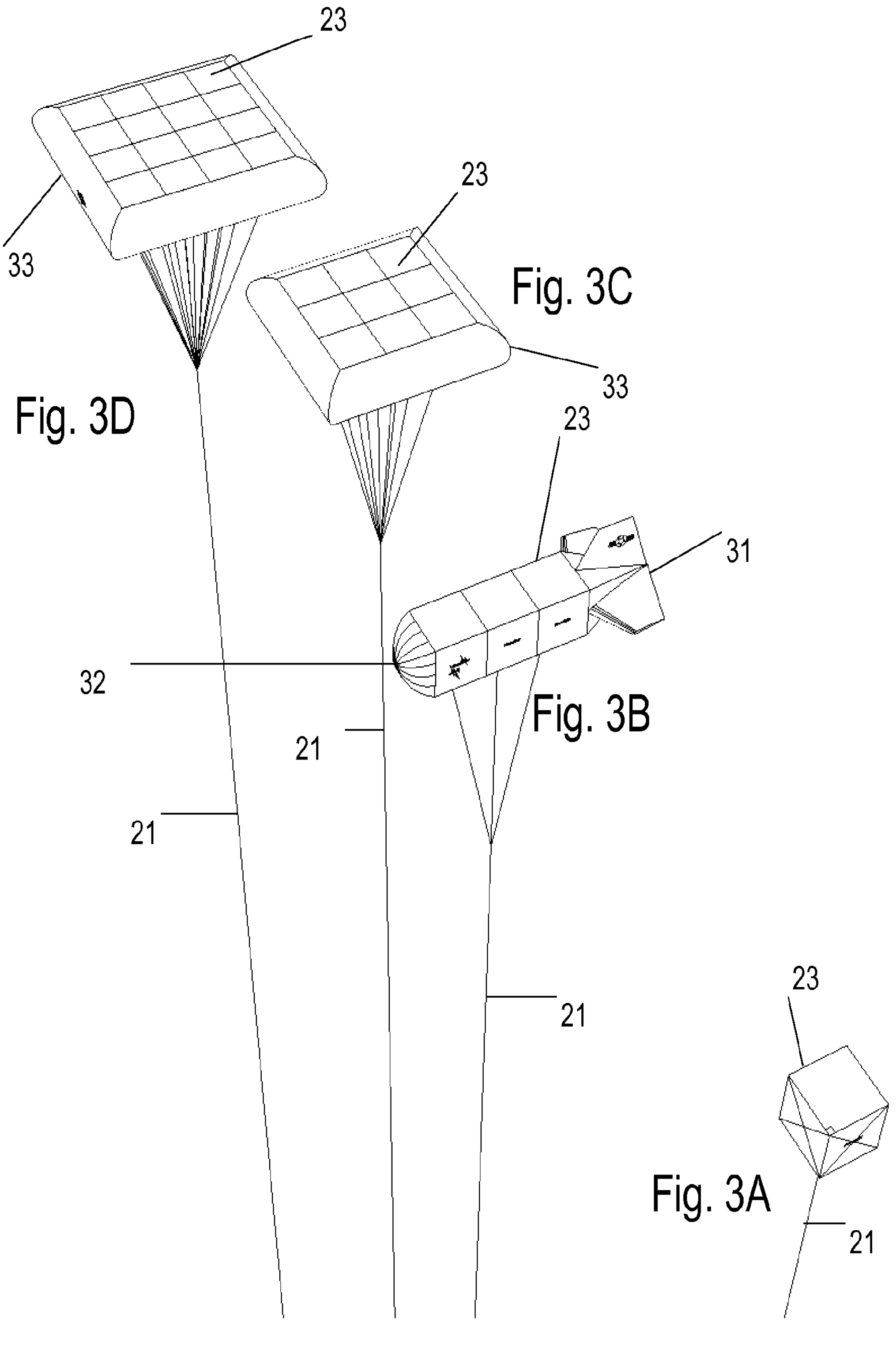

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Fig. 3C
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Fig. 3D
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Fig. 3B
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Fig. 3A
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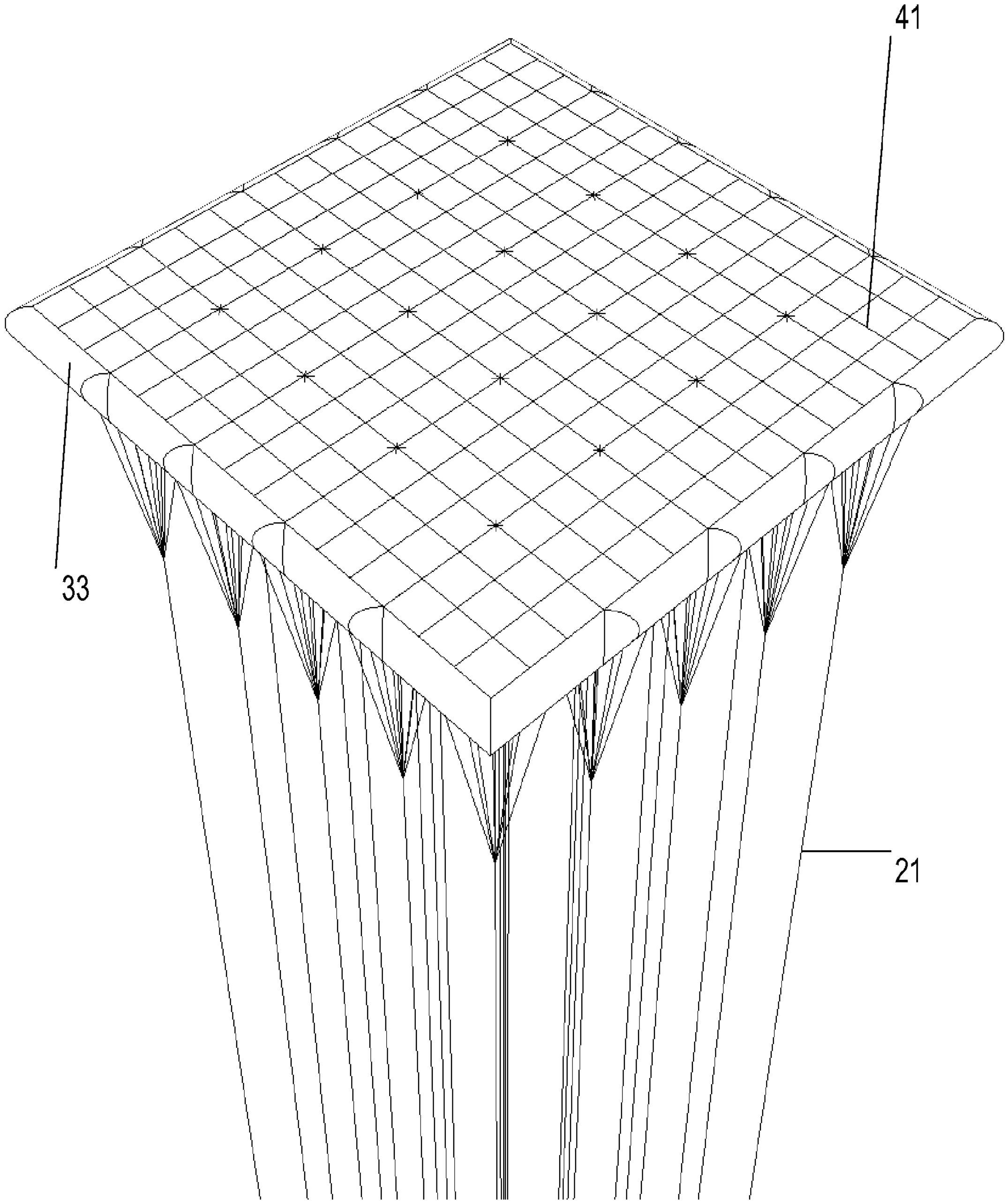

Fig.4

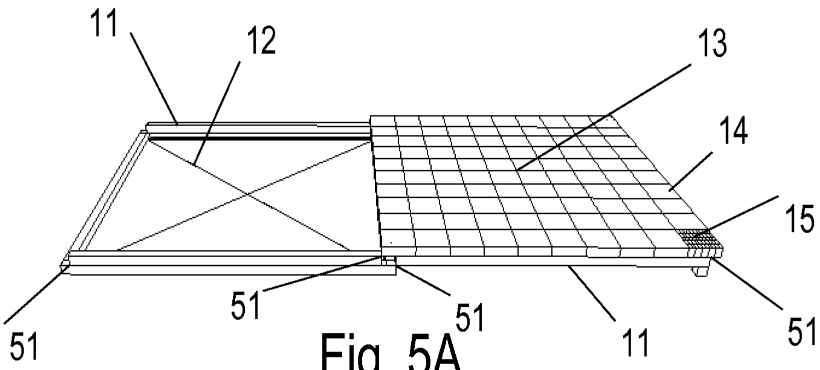

Fig. 5A

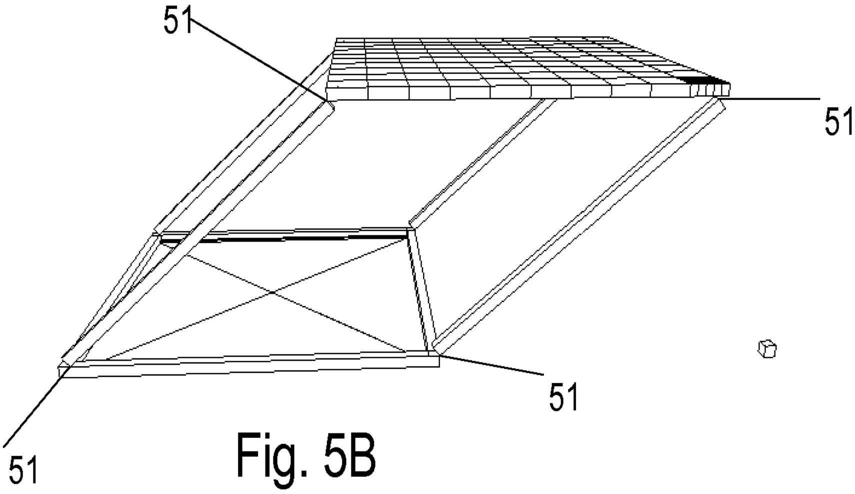

Fig. 5B

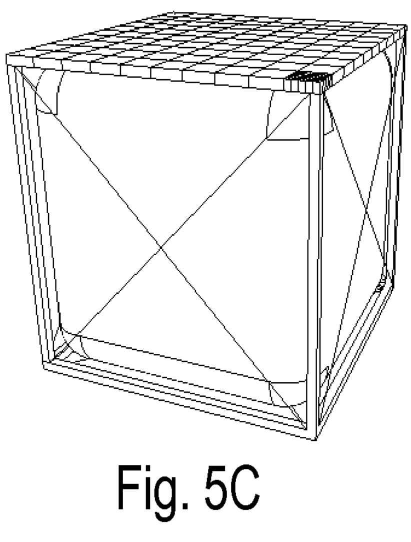

Fig. 5C

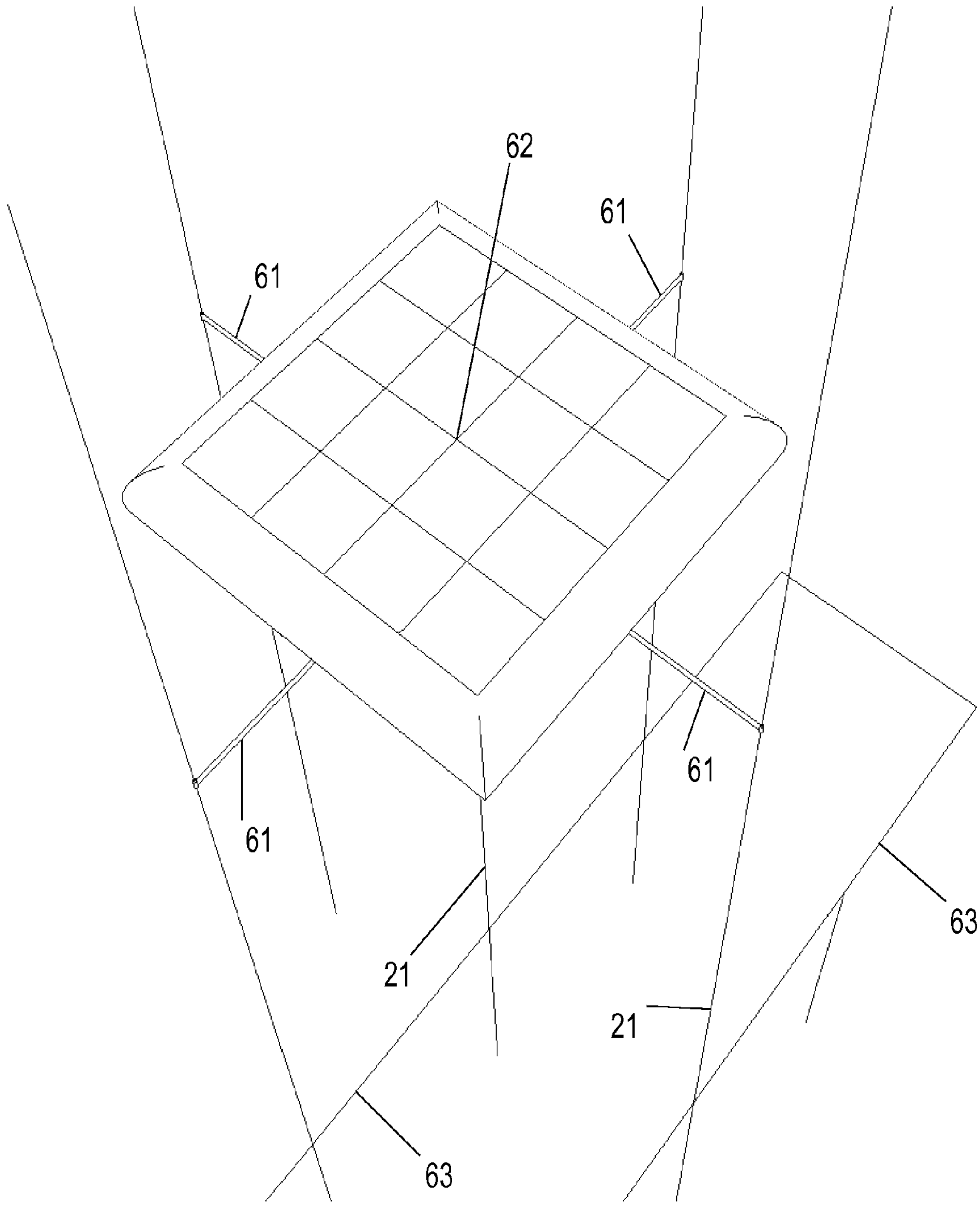

Fig. 6

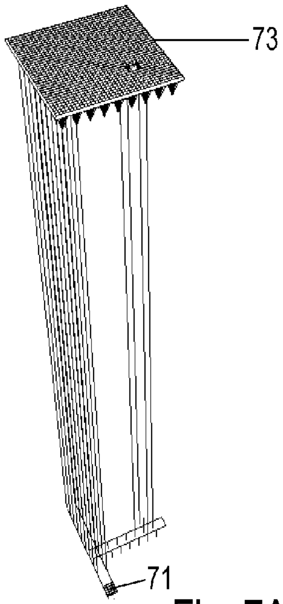

Fig. 7A

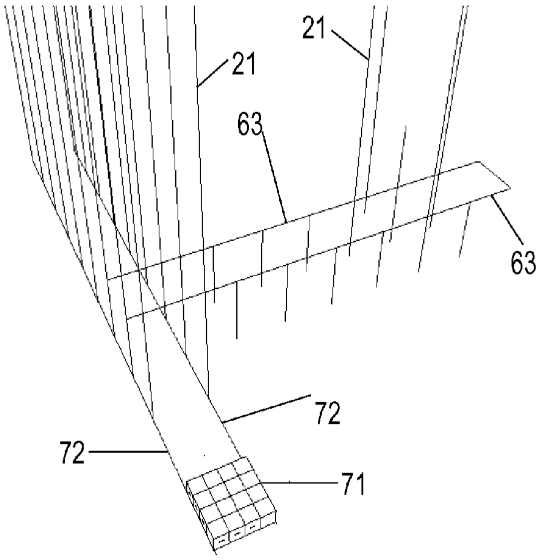

Fig. 7B

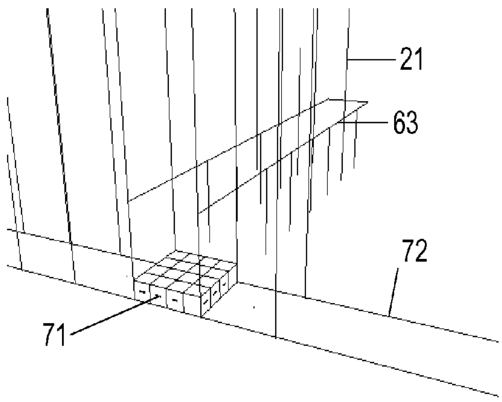

Fig. 7C

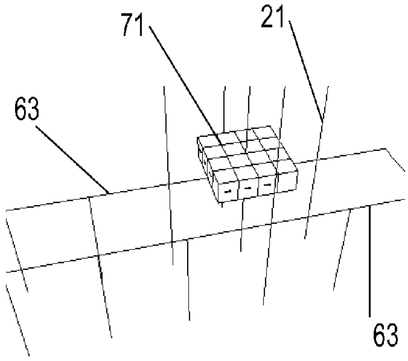

Fig. 7D

STRATOSPHERE TETHERED PHOTOVOLTAIC POWER PLATFORM

CROSS-REFERENCE TO RELATED APPLICATIONS

Non-provisional application Ser. No. 12/430,869, filed on Apr. 27, 2009. Non-provisional application Ser. No. 12/488,852, filed on Jun. 22, 2009.

FEDERALLY SPONSORED RESEARCH

Not Applicable

SEQUENCE LISTING OR PROGRAM

Not Applicable

BACKGROUND

1. Field

This invention generally relates to solar energy systems, and more particularly to photovoltaic electrical energy solar energy systems.

2. Prior Art

Photovoltaic (PV) solar energy systems use solar cells to convert solar energy directly into electricity. The solar cells are usually connected together in panels, which in turn are mounted on mechanical supports and connected together to form arrays. Associated with the panels are electrical elements such as conductors, voltage converters, combiners, fuses, relays surge protectors and inverters used to combine the power from the collection of panels into a single power output.

Current photovoltaic electricity systems suffer from several problems. Their high capital costs make the cost of the energy they produce uncompetitive without subsidy.

The power produced by PV panels varies by more than a factor of two depending on their geographic location. Large-scale systems in the best sunny geographic locations also have high ancillary costs to compensate for the long transmission distance from the system to the average power user.

Photovoltaic arrays need to have large entry apertures to produce meaningful amounts of power. Utility scale systems have apertures measured in millions of square meters. Current systems consequently consume large areas of land and significant quantities of construction materials like glass and steel needed to fabricate this large aperture array.

Weather in the form of dust, wind, rain, hail, frost and snow make power generation unpredictable and require that structures be strong and durable which adds significantly to their cost. Typical design wind loads are around 2000 Pa and mechanical snow loads are around 5000 Pa.

Some current large scale systems use large arrays of individually steered collecting elements. Robust mechanical support, motors, gears, electrical equipment etc are needed for each collector element, contributing significantly to overall cost.

The cost problem is compounded by the generally low overall energy conversion efficiency of current systems, which consequentially requires a larger surface area and more material to produce a given power output compared to higher conversion efficiency systems.

Another area of prior art is buoyant airships and balloons that float in the atmosphere. Balloons float freely without propulsion and are constructed from gas tight flexible membranes, containing a lighter than air gas, sometimes pressurized and sometimes unpressurized. Airships have an aerodynamic shape and a means of propulsion and are categorized as rigid, semi rigid or blimps.

Blimps use a gas tight membrane filled with a pressurized lighter than air gas to provide both buoyancy, structural rigidity and an aerodynamic shape. This means of construction has limited their scale to a volume of a few thousand cubic meters. They either have a means of propulsion or they are tethered to the ground. A tethered blimp lacking means of propulsion is usually called an aerostat.

Rigid airships are constructed with a rigid framework that provides structural rigidity and aerodynamic shape and contain un-pressurized gas bags within the rigid framework to provide buoyancy. This means of construction has enabled the construction of craft with volumes exceeding 100,000 cubic meters. Rigid and semi rigid airships have all been powered aircraft. Airships and tethered blimps have only operated at altitudes below 10 km.

There have been some proposals to attach PV cells to tethered aerostats to generate power. These have all proposed current small scale aerostats tethered at relatively low altitudes in the troposphere. None of these proposals have been reduced to practice because of practical constraints that make them unrealistic. At all altitudes in the troposphere, weather can be severe and the durability of current aerostat technology is poor. The small scale of aerostats mean that they can at best only provide a small amount of power, and many thousands would be needed to provide power at a utility scale of hundreds of mega Watts. They would need to be spaced far apart to avoid colliding. There would be a constant need to winch them down for maintenance and to avoid weather.

The earth's atmosphere in the low stratosphere in the region of 20 km altitude has benign weather properties over most of the earths surface below latitude 60 degrees that make it attractive for long endurance operation. This has been exploited by reconnaissance aircraft like the U2 and Global Hawk. Weather we are familiar with is confined to the troposphere which extends up to an altitude from about 8 km to 12 km with a gradual transition to the stratosphere called the tropopause. The high winds of the jet stream occur at the tropopause. There is no moisture or clouds in the stratosphere and turbulent weather patterns like thunderstorms and hurricanes do not reach high enough to have effect at an altitude of 20 km. This is well illustrated by flights by U2 and Global Hawk over hurricanes for weather research. Winds are steady and horizontal, mostly less than 20 meters per second, with small episodic periods in winter of a few weeks every few years where they can reach 40 meters per second due to excursions of the polar vortex which circles the poles in the stratosphere in winter.

The permanently benign weather properties of the atmosphere in the region of 20 km altitude in the low stratosphere make it a distinct and separate operational environment which enables practical long endurance operation as evidenced by the U2 and global hawk aircraft. The unique environment requires unique aircraft designed to operate there. Conventional aircraft are designed to operate at lower altitudes up to around 12 km, and cannot operate at altitudes around 20 km. There have been attempts at building long endurance high altitude airships to fly at 20 km altitude and above, but none have as yet succeeded due to the difficult engineering challenges posed by the thin atmosphere. In the class of buoyant aircraft, only un-tethered and un-powered free floating weather and research balloons have operated in the stratosphere.

Another feature of the environment in the low stratosphere is sunlight is more intense. Atmospheric scattering is much reduced due to the much smaller mass of air in the optical path, especially at lower sun elevation angles. This results in higher daily solar energy incident on a surface. This can exceed a factor of three or more times ground level solar energy at the same location depending on latitude and tracking. Also solar energy is totally predictable as it is not interrupted by weather or dust. No prior art airship or aerostat has been designed to stay aloft on a permanent basis. Endurance is measured in weeks for airships and months for aerostats. They both have limited endurance and both must avoid bad weather.

In summary all prior art mechanisms that float in the atmosphere have been relatively small scale and short endurance and almost all have operated in the troposphere. There have been no tethered buoyant structures operated in the atmosphere at any altitude that have the equivalent scale or endurance of permanent buoyant structures in the ocean, such as tension leg platforms or anchored platforms.

SUMMARY

The present invention is realized by apparatus and methods for placing a large utility scale photovoltaic array in the low stratosphere of earth's atmosphere at an altitude of about 20 km, above clouds, moisture, dust, and wind. This is accomplished using a large light-weight, rigid, buoyant structure to support the large photovoltaic array. Long, strong and light tether(s) connect the buoyant structure to the ground which hold it in position against wind forces. The electricity output from the PV array is then coupled to high voltage transmission line(s) which connect from the platform to the earth's surface. The electricity is then transmitted through the high voltage transmission line(s) to the earth's surface where it is connected to the electrical supply grid and provides lower cost, more reliable electricity.

These and other objects and features of the invention will be better understood by reference to the detailed description which follows taken together with the drawings in which like elements are referred to by like designations throughout the several views.

DRAWINGS

Figures

FIG. **1** is a perspective view of a PV platform module designed in accordance with the present invention.

FIG. **2**A is a perspective view of a buoyant PV platform module with an attached tether and winch designed in accordance with the present invention.

FIG. **2**B is a perspective view of a PV platform module designed in accordance with the present invention at high altitude.

FIG. **3**A is a simplified perspective view of the buoyant PV platform module shown in FIG. **1** and FIG. **2**.

FIG. **3**B is a perspective view of a small PV platform assembled from three of the PV platform modules shown in FIG. **3**A with an added inflated nose cone and tail section.

FIG. **3**C is a perspective view of a small PV platform assembled from nine of the PV platform modules shown in FIG. **3**A with an added inflated aerodynamic edge.

FIG. **3**D is a perspective view of a small PV platform assembled from sixteen of the PV platform modules shown in FIG. **3**A with an added inflated aerodynamic edge.

FIG. **4** is a perspective view of a large PV platform assembled from twenty five of the nine PV platform module, small PV platform elements shown in FIG. **3**C with an added inflated aerodynamic edge.

FIG. **5**A is a perspective view of a PV platform module assembled folded flat on the ground.

FIG. **5**B is a perspective view of a PV platform module unfolded to about 30 degrees.

FIG. **5**C is a perspective view of a PV platform module fully unfolded to vertical with cross bracing and gas bag added.

FIG. **6** is a perspective view from above of a small PV platform made from 16 PV platform modules, during vertical deployment to form part of a large platform.

FIG. **7**A is a perspective view from above of a large platform constructed from 81, small PV platforms, each small PV platform being constructed from 16 PV platform modules, as a small PV platform is being added to the large platform.

FIG. **7**B is a perspective view of a close up of the bottom front left of FIG. **7**A.

FIG. **7**C is a perspective view of a stage in the deployment of the small PV platform.

FIG. **7**D is a perspective view of a subsequent stage in the deployment of the small PV platform.

DRAWINGS

Reference Numerals

11	strut	12	cable cross brace
13	top surface structure	14	top surface section
15	PV panel top surface	16	interior gas bag
21	tether-HV cable	22	winch
23	PV platform module	31	inflated tail section
32	inflated nose section	33	inflated edge section
41	9 module small PV platform	61	deployment boom
62	16 module, small PV platform	63	in guides or rails
71	16 module, small PV platform	72	across guides or rails
73	large platform made of 81, small PV platforms		

GLOSSARY

The specification uses several standard definitions throughout to avoid ambiguity. These related definitions are tied to specific aspects of the description.

PV platform module: the standard and smallest unit of construction.

Small PV platform: An assembly of PV platform modules.

Large platform: An assembly of small PV platforms.

DETAILED DESCRIPTION

FIG. **1** shows a perspective view of a buoyant photovoltaic (PV) platform module designed in accordance with the present invention. It consists of a rigid framework formed from struts **11**, top surface **13** and cross bracing cables **12**. The interior of the framework holds a gas bag **16**, which contains the buoyancy gas, commonly hydrogen or helium. The top surface **13** is assembled from smaller structural sections **14**. The top surface of each structural section **14** supports an array of PV panels **15**. The PV panels **15** are connected electrically with wires, DC-DC voltage converters, combiners and electricity distribution hardware to provide high voltage (HV) power output from the platform. This HV output can be AC or DC. In this embodiment when fully assembled, the overall structure is a rigid cross braced cube. The length of the cube is in the region of 100 meters. The dimensions are set by the buoyancy available at the design altitude. The module buoyancy supports the mass of the module and the wind loads. The buoyant photovoltaic (PV) platform module described can be used as a module in a modular construction system or method used to build larger buoyant platforms from assemblies of modules. For simplicity in the description we subsequently refer to these cubic buoyant photovoltaic (PV) platform modules as PV platform modules. Embodiments are not restricted to cubes, and other geometric forms are feasible. A particular variant has a height that is different than the width. This allows a simple change in vertical strut length and gas bag height to provide different buoyancies. This allows embodiments with different payloads or operational altitudes to be easily constructed.

Equipment and materials need to operate within the environmental constraints of the low stratosphere. Air pressure is about 8000 Pa which affects buoyancy and the breakdown voltage. The air temperature is around −60 degrees Celsius, and the ozone concentration is around 2.8 ppm. These affect the choice of materials, particularly plastics that may become more brittle or suffer damage. The struts and top surface are lightweight, rigid truss frameworks, typically formed from aluminum. The gas bag is typically a thin plastic membrane. A commonly used material is polyethylene film around 25 microns thickness. The membrane may be a laminate or co-extrusion of several plastic and metal materials to provide properties such as low buoyancy gas permeability, protection from ozone, weld-ability and strength.

PV panels are of lightweight construction, typically weighing about 2 kg per square meter or less. Various PV cell technologies can be employed including commonly used crystalline and polycrystalline silicon. Given the predominance of direct solar radiation in the low stratosphere, concentrating PV panels that need to track the sun may benefit. PV panel materials need to handle the cold and the UV, particularly the PV cell encapsulant material. Silicone is one good choice. Compared to PV panels on the ground, the need for water based weather protection is reduced as there is no water in the low-stratosphere operating environment. Ground based PV panels as well as handling water based weathering, also have to handle snow loads of around 5000 Pa, hail, regular washing, and maximum wind loads of around 2000 Pa. In contrast, in the low-stratosphere there is no hail, snow, or significant dust, and maximum wind loads are about 125 Pa, so PV panels can be simpler and less robust. PV panels are highly reliable, and the absence of water based weather degradation and the low operating temperature will enhance this reliability in the low-stratosphere.

Arrays of PV panels **15** can be formed in the same ways they are on the ground. The simplest form is a flat array covering the surface. Single fixed axis, one axis tracking and two axis tracking are all also possible. Because the structural array has a cost per unit area, optimizing the area usage is more important than with ground based arrays, and is similar to ground based commercial systems on roofs that want to optimize the electricity generated for the roof area. As with ground based arrays detailed cost analysis based on the cost of panels, the additional costs of tracking apparatus and the geographic location determine what is the most cost effective array form to deploy.

Embodiments of PV platform modules may not cover the entire surface with a PV array (**15**), or even any PV panels. As part of a larger platform they may serve other roles, such as providing active and passive fire safety, by providing fire suppressants or acting as a non flammable fire break. They may also support other payloads such as wireless or laser communication systems for communication with the ground, space, or other stratospheric platforms. They may also support radar systems for uses such as monitoring weather, air traffic control and military uses. They may also support observation systems such as space telescopes and ground monitoring. They may also support scientific payloads.

FIG. **2**A shows a different perspective view of the PV platform module shown in FIG. **1**. The module is the same as in FIG. **1** with the addition of tether/HV cable **21** and winch **22**. The module is shown during deployment, floating at about 100 meters altitude and being held by the tether/HV cable **21**. The gas bag **16** is shown in a partially inflated condition. As the module rises in altitude and atmospheric pressure reduces, the gas bag expands. Sufficient buoyancy gas is added to the gas bag such that it is nearly fully inflated at a nominal operational altitude of about 20 km. Throughout this specification reference to 20 km altitude is meant to be interpreted as approximately 20 km. The low stratosphere varies in altitude and the precise operational altitude of PV platforms will vary by location, and perhaps by season. The tether may include the High Voltage (HV) cable that carries power from the module to the ground. The tether is strong and lightweight and typically made from an aramid fiber such as Kevlar. For efficiency and simplicity the high voltage is typically direct current (HVDC). The combination of high voltage transmission and aluminum conductors keeps the HV transmission cable lightweight.

FIG. **2**B shows the PV platform module deployed to a high altitude, on its way to operational altitude. Winch **22** is playing out the cable **21**. The platform **23** is shown in detail in FIG. **1**.

Compared to prior art airships and aerostats, a novel feature of the PV platform module **23** described above is the scale. The basic 100 meter cube module **23** has an approximate buoyancy volume of 1,000,000 cubic meters, which far exceeds the 200,000 cubic meters of the Hindenburg, still the largest airship ever built. The scale is necessary because the air at 20 km altitude is very thin and a ratio of volume to top surface area of about 100 is needed to carry the structural, HV cable and wind loads resisted by the tether.

The rigid framework provides the support structure for the PV panels and carries the wind induced loads. A simple gas bag needs no control mechanisms to adjust for pressure changes and as an example the buoyancy gas leakage for a gas bag of these dimensions constructed with 25 micron aluminized PET membranes is considerably less than 1% a year. For PV platforms with a design life of 20 to 30 years, buoyancy gas may not have to be replenished for the life of the platform. Endurance measured in decades is more accurately described as a design life, a term normally applied to structures such as buoyant ocean platforms or bridges.

FIGS. **3**A, **3**B, **3**C and **3**D show small PV platforms assembled from PV platform modules **23**. FIG. **3**B shows a small PV platform constructed from three mechanically connected PV platform modules **23** with an attached inflated nose **32** and tail **31**. The tether **21** attaches to each PV platform module to distribute the mechanical load and combine the HV power output from each PV platform module. FIG. **3**C shows a small PV platform constructed from nine mechanically connected PV platform modules **23** with an attached inflated rounded aerodynamic edge **33**. FIG. **3**D shows a sixteen PV platform module **23** small PV platform with an inflated rounded aerodynamic edge **33**. Inflated edge **33**, nose **32** and tail **31** are each gas-tight, light-weight fabric containers filled with pressurized gas, most commonly air. The gauge pressure might be in the region of 300 Pa to 500 Pa. Commonly used fabrics are laminates of materials that provide various properties. An example of such a laminate might have an exterior layer of polyvinyl fluoride film for protection from weather, a layer of polyester fabric for strength and an inner layer of polyurethane film for gas tightness.

Each of these small PV platforms are assembled on the ground and then deployed to 20 km altitude similar to as shown in FIG. 2B. FIGS. **3**A, **3**B, **3**C and **3**D show small PV platforms deployed as small stand alone power plants. The sixteen PV platform module, small PV platform shown in FIG. **3**D measures about 400 meters on a side. The difficulty of manufacturing and deploying larger assemblies of PV platform modules **23** leads to the method shown in FIG. **4**.

FIG. **4** shows a large platform composed of 25 of the small PV platforms, each constructed from 9 PV platform module assemblies **41** shown in FIG. 3C, mechanically connected together and deployed at 20 km altitude. As can be seen each small PV platform **41** has its tether/HV cable **21** attached. Each small PV platform **41** is individually assembled on the ground and then deployed to 20 km altitude using its own tether/HV cable **21** and winch **22**. On its ascent, each small PV platform **41** is guided by attached booms that connect to adjacent tethers of previously deployed small PV platforms **41** and use them as guides and for horizontal support. This ensures that the deploying small PV platforms **41** do not collide with adjacent tethers and also the adjacent tethers provide mechanical support to help the deploying small PV platforms **41** resist wind loads. It also ensures that small PV platforms **41** can be simply and accurately guided into their mating position within the larger platform where they can be mechanically connected to become part of the larger platform structure. This process is reversed to bring small PV platforms **41** down to the ground for maintenance or repair. The large platform only ever exists at 20 km altitude and only small PV platforms **41** are handled on the ground. This terminology distinguishing between small and large platforms is standardized in this description. Large platforms are always assembled from small platforms at altitude in the low stratosphere. Small platforms are always assembled on the ground from PV platform modules.

The large platform shown in FIG. **4** has 25 tethers. This provides directional stability and redundancy. Compared to a single small PV platform **41**, the large platform has 25 times the buoyancy, but only five times the frontal area, and so is deflected far less in high winds. As large platforms grow, this effect continues and platforms become more stable and redundant.

FIGS. **5**A, **5**B, and **5**C illustrate part of a method to construct a PV platform module **23**. FIG. **5**A shows the module structure assembled folded flat on the ground. This allows construction and assembly to occur conveniently at ground level. When the assembly of the structure including all PV and electrical assembly is complete and tested at ground level, the structure is unfolded to its final cubic configuration. Hinged joints **51** at the eight vertices of the cube connect the structural elements and enable the unfolding from flat to cubic. The forces used to raise the structure could be cables and pulleys which are not shown. FIG. **5**B shows an intermediate position as the module is unfolded. FIG. **5**C shows the final position where the joints have been rigidly connected and the hinges are locked and no longer operate. The cross bracing has been added and the gas bag is shown added and inflated.

The method shown can be easily extended to unfold multiple joined PV platform modules from a folded flat position using hinges at the vertices of each cube. These small PV platforms can then be deployed to high altitude and joined to form a single large multi element structure using the method described in the description for FIG. **4** and FIG. **7**.

Another embodiment of the folding method described would break the vertical struts with additional hinges and fold the struts under the platform surface.

FIG. **6** shows a perspective view of a small PV platform **62** assembled from 16 PV platform modules **23** as small PV platform **62** is deploying to altitude. This illustrates the method of deployment described in the description for FIG. **4**. For clarity only the nearest neighbor tethers **21** are shown. This shows the guiding and supporting booms **61** attaching the small PV platform to the adjacent tethers **21**. As a winch plays out the tether attached to small PV platform **62** the small PV platform rises or falls vertically in a controlled manner accurately positioned and restrained horizontally by the booms **61**.

During initial assembly of the large platform, there are few deployed small PV platforms and supporting tethers for guidance. Unique deployment methods are required using additional cables to help guide and support deploying platforms **41** or **62**.

FIGS. **7**A, **7**B, **7**C and **7**D show various perspective views describing additional stages of small PV platform **71** deployment described in the description of FIG. **6**. In all views, most of the tethers **21** are omitted for clarity.

FIG. **7**A shows a perspective view of a large platform **73** floating at altitude. An assembled small PV platform **71** is shown at the bottom, about to be deployed to altitude.

FIG. **7**B shows a close up perspective view of small PV platform **71** and elements that enable its deployment. In-rails or guides **72** are used to help guide and transport small PV platform **71** through the space between the tethers **21** to the location of the across-rails or guides **63**.

FIG. **7**C shows a perspective view of a stage of deployment of small PV platform **71** when it has completed its transport along in-rails **72**. In this embodiment across-rails **63** are shown above in-rails **72**, but they could be at the same level as in-rails **72**, with either or both at ground level or elevated using the tethers **21** as support.

FIG. **7**D shows a perspective view of small PV platform **71** after it has transferred via across rails **63** to the desired tether **21** location for vertical transport. The vertical stage in deployment is shown in FIG. **6**, where booms are deployed and attached to adjacent tethers **21** and aerodynamic edges are inflated.

Operation

The small PV power plants floating tethered in the low stratosphere shown in FIGS. **3**B, **3**C and **3**D, and the large platforms shown in FIGS. **4**, and **7**A operate to produce electricity in the manner of prior art PV power plants on the ground. The electrical elements, including PV panels, wires, combiner elements, DC-DC converters, DC-AC inverters are the same but have to be designed to operate in the unique environment in the low stratosphere, which is colder, has thinner air with low buoyancy and a low breakdown voltage, has more ozone and has higher intensity solar radiation with more UV. They also can be optimized for operation in the low stratosphere, as is the case for PV panels which don't have to handle water based weather and are exposed to much lighter mechanical loads from wind and the absence of snow, hail and ice.

When deployed and operating in the low stratosphere, the small PV platforms like those shown in FIGS. **3**A, **3**B, **3**C and **3**D, and the large platforms shown in FIGS. **4**, and **7**A operate passively to resist wind loads and atmospheric changes. The structures move under wind loads and buoyancy provides reaction forces to counteract wind forces. The volume of gas in gas bags expands and contracts within the range of pressure changes at the deployed altitude.

Tether/HV cables **21** are also subject to extreme wind speeds in the troposphere, but their narrow diameter ensures that the aerodynamic loads are small in comparison to the forces on the buoyant platform and these forces are also counteracted by platform buoyancy reaction forces.

Operation also includes deployment and maintenance and repair. The physical scale of the buoyant structures shown in FIGS. **3**A, **3**B, **3**C, **3**D, **4**, and **7**A is larger than any prior art buoyant apparatus. The apparatus and methods that enable construction and deployment of such large scale objects is by definition new. The design of PV platform modules **23** is described in the description of FIG. **1** and FIG. **2**. Each PV platform module is a fully functional self contained array of PV panels, electrical systems, structural systems and buoyancy systems. This greatly facilitates the construction of larger structures from assemblies of these modular elements which simply need to be mechanically connected. The method of construction of PV platform modules **23** shown in FIGS. **5**A, **5**B, and **5**C that enables all assembly work to occur at ground level greatly simplifies the construction process. The addition of appropriate hinges **51** at the vertices of PV platform modules **23** enables this form of construction.

The area of flat land needed along with logistical and operational difficulties make it impractical to construct, deploy and maintain very large platforms from the ground. The method of small PV platform deployment shown in FIGS. **6**, **7**A, **7**B, **7**C, and **7**D using guide rails **63** and **72** moves the assembly process of large platforms to the low stratosphere. This process of deployment, maintenance and recovery of small PV platforms that can be reasonably assembled and repaired on the ground and joined together only in the low stratosphere makes the construction of large platforms possible. The large platforms only ever exist as such in the stratosphere. The assembly area on the ground is small and if guide rails **63** and **72** are elevated, the ground under the large array is undisturbed during operation and maintenance. Over time with proven safety and reliability, large platforms could become very large as the only additional impact on the ground with large platform growth is winches and HV distribution.

With low leakage gas bags and highly reliable and redundant PV panels and electrical systems, it is likely that platforms will stay aloft for years before maintenance or repair is required. When necessary, the method and apparatus shown in FIGS. **6**, **7**A, **7**B, **7**C, and **7**D allows small PV platforms to be winched down and repaired or replaced when it is operationally convenient.

Each small PV platform in the large platform has its own tether. This, as well as allowing for maintenance and repair provides tether redundancy and ensures that mechanical loads on the platforms are evenly distributed. This in turn reinforces the modular structural design as mechanical loads are constant or reduce as the large platforms grow.

Though not shown or discussed PV platform modules have systems to handle static electricity and lightning. There are instrumentation systems to monitor the electrical, structural, buoyancy systems, gas leakage, fire environmental pressure, temperature, sunlight and other variables. There are control systems to handle system deployment, fire and electrical safety systems.

Also not shown or discussed are other uses of the small or large platforms for communications or observation for both civilian and military use. These uses could be added to PV power platforms or be provided on platforms not primarily designed to provide electricity.

ADVANTAGES

Because of exposure to more solar energy and the cold operating environment that increases the efficiency of many solar cell technologies, the electric power output is many times that of a same sized prior art ground PV system. This means the cost of the electricity produced is lower.

Power output is high at high latitudes, and is not affected by clouds, dust, or bad weather. This is of particular benefit to normally cloudy northern and mid latitude locations where most large urban areas are located.

The combination of geographic flexibility and power generation without the need for any fuel provides a secure and clean energy system.

Power in the form of electricity can be provided at any point on the earth's surface, where the definition of surface includes the entire surface, including all land and oceans. Offshore platforms, or platforms that straddle land and ocean could be a particularly convenient in some locations. PV electricity could be provided near mines, allowing convenient processing without transportation of bulk ores.

The small amount of land area needed means that systems can be located very near existing power plants, or existing transmission and distribution networks, which reduces or eliminates the need for new electricity transmission infrastructure.

Systems can scale to very large size. This means that fewer platforms are needed which reduces the impact on aircraft and airspace.

Because the land and environmental impact is small, the platforms use commonly available materials that have no resource or manufacturing constraint and the generated electric power is low cost, the systems can scale to provide all needed energy. The lack of energy generation at night can be handled with several technologies. The most generally useful is to manufacture synthetic fuels which can be used for both nighttime electricity generation and for transportation.

Energy systems that do not put carbon dioxide into the atmosphere are highly desirable. Currently all alternative energy systems suffer from major problems:

1) They are very costly to build

2) They are unreliable providers of electricity due to intermittent weather effects, and so need backup generation using alternate energy sources such as natural gas.

3) They need large additional energy storage and transmission infrastructure investments.

4) The most abundant energy is located far from users, again requiring large transmission infrastructure investments.

5) They require large areas of land which increases their environmental impact and limits their use to areas where both energy and land are available.

This new system has the benefit of not producing carbon dioxide and has none of these problems. The bottom line is clean secure energy can be provided at much lower cost and minimal environmental impact.

The benefits of suspending a PV array in the stratosphere are the reliability of the energy source, the higher incident energy density, and the benign stable calm low wind weather free environment that enables permanent tethering. These benefits come at the price of lower atmospheric density, which means less buoyant lift and a consequent need for a large lightweight structure.

The modular manufacturing and deployment methods described greatly reduce cost, improve quality, and speed construction. It is envisaged that when production is mature, complete utility size electricity generating facilities could be operational in less than a year from breaking ground. This compares with current technologies which require three to five or more years to construct.

Although the present invention has been described in terms of a first embodiment, it will be appreciated that various modifications and alterations might be made by those skilled in the art without departing from the spirit and scope of the invention.

The invention should therefore be measured in terms of the claims which follow.

What is claimed is:

1. A method of assembling an airborne platform for generating electricity, comprising:

a) providing a first plurality of photovoltaic (PV) panel modules, each module comprising a PV panel, a rigid truss framework, and an inflatable gas bag;

b) assembling the first plurality of PV panel modules into a first sub-platform by mechanically and electrically connecting adjacent PV panel modules to each other;

c) tethering the first sub-platform to the ground with a first tether;

d) deploying the first sub-platform to the stratosphere by inflating the gas bags of the first plurality of PV panel modules with a lighter-than-air gas;

e) providing a second plurality of PV panel modules, each module comprising a PV panel, a rigid truss framework, and an inflatable gas bag;

f) assembling the second plurality of PV panel modules into a second sub-platform by mechanically and electrically connecting adjacent PV panel modules to each other;

g) tethering the second sub-platform to the ground with a second tether;

h) attaching a boom between the second sub-platform and the first tether;

i) deploying the second sub-platform to the stratosphere by inflating the gas bags of the second plurality of PV panel modules with a lighter-than-air gas, wherein the boom maintains the spacing between the first tether and the second sub-platform while the second sub-platform is deploying; and

j) assembling a platform from the first and second sub-platforms in the stratosphere, wherein the boom mechanically connects the first and second sub-platforms.

2. The method of claim 1, further comprising:

a) providing at least one additional plurality of PV panel modules, each module comprising a PV panel, a rigid truss framework, and an inflatable gas bag;

b) assembling each of the plurality of PV panel modules into a sub-platform by mechanically and electrically connecting adjacent PV panel modules to each other; and

c) tethering each of the at least one additional sub-platforms to the ground with a corresponding tether;

d) deploying each of the at least one additional sub-platforms by (i) positioning the sub-platform adjacent to at least one previously-deployed sub-platform tether, (ii) for each adjacent previously-deployed tether, attaching a boom between the sub-platform and the tether, (iii) deploying the sub-platform to the stratosphere by inflating the gas bags of the plurality of PV panel modules of the sub-platform with a lighter-than-air gas, wherein the at least one boom maintains the spacing between the at least one adjacent previously-deployed tether and the sub-platform while the sub-platform is deploying, and (iv) mechanically attaching the sub-platform to the platform with the at least one boom.

3. The method of claim 2, further comprising:

a) providing rails or guides to transport each of the at least one additional sub-platforms horizontally through the array of previously-deployed tethers to a desired location for vertical deployment;

b) wherein each boom comprises sliding or rolling connectors for sliding or rolling along the corresponding tether.

4. The method of claim 1, wherein the step of tethering the first sub-platform to the ground with a first tether further comprises tethering the first sub-platform to the ground with a first high-voltage cable; and wherein the step of tethering the second sub-platform to the ground with a second tether further comprises tethering the second sub-platform to the ground with a second high-voltage cable.

5. The method of claim 4, further comprising:

a) combining the electrical output of said photovoltaic panels;

b) converting said electrical output to a high-voltage output;

c) transmitting said converted high-voltage electrical output to the ground.

6. The method of claim 4, wherein the tether and high-voltage cable of each sub-platform has a unified, one-piece construction.

7. The method of claim 4, wherein the high-voltage cables transmit high-voltage direct current.

8. The method of claim 1, wherein providing a first and a second plurality of PV panel modules further comprises, for each PV panel module:

a) providing a truss structure comprised of struts connected by hinges, wherein the truss structure is initially folded substantially flat;

b) unfolding the hinges of the truss structure, thereby creating a three-dimensional truss framework; and

c) mechanically fixing the struts to one another, thereby creating a rigid truss framework.

9. The method of claim 1, wherein the PV panels are resistant to ozone and intense ultraviolet light and are operational at −65 degrees Celsius.

10. The method of claim 1, wherein exterior vertical surfaces of said platform are formed from pressurized inflated elements.

11. The method of claim 1, wherein each tether is constructed from aramid fiber or ultra-high molecular weight polyethylene (UHMWPE) fiber.

12. An airborne platform operating in the low stratosphere comprising:

a platform floating in the low stratosphere constructed from a plurality of mechanically connected sub-platforms;

each sub-platform comprising a plurality of photovoltaic (PV) panel modules, and further comprising a tether and high-voltage cable mechanically and electrically connecting the sub-platform to the ground;

each module comprising a PV panel, a rigid truss framework, and a gas bag inflated with a lighter-than-air gas;

wherein, when at least one of said sub-platforms is floating in the low stratosphere, at least one other sub-platform is positioned on the ground adjacent the tether or tethers of the at least one floating sub-platform and is connected to said adjacent tether or tethers by a corresponding boom or booms;

whereby the at least one other sub-platform is configured to be deployed vertically to the platform and mechanically connected to the platform by said boom or booms such that each of said booms translates along the length of the corresponding tether as the sub-platform is deployed.

13. The airborne platform of claim 12, further comprising electrical connections for combining the electrical output of said PV panels, wherein said electrical output is converted into a high-voltage output and transmitted to the ground.

14. The airborne platform of claim 12, wherein the PV panels are resistant to ozone and intense ultraviolet light and are operational at −65 degrees Celsius.

15. The airborne platform of claim 12, wherein the tether and high-voltage cable of each sub-platform has a unified, one-piece construction.

16. The airborne platform of claim 12, wherein the high-voltage cables transmit high-voltage direct current.

17. The airborne platform of claim 12, wherein exterior vertical surfaces of said platform are formed from pressurized inflated elements.

18. The airborne platform of claim 12, wherein each tether is constructed from aramid fiber or ultra-high molecular weight polyethylene (UHMWPE) fiber.

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