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(54) Title: SYSTEMS AND METHODS INCLUDING FEATURES OF SYNCHRONIZED MOVEMENT ACROSS AN ARRAY OF SOLAR COLLECTORS

(57) Abstract: Systems and methods are disclosed related to solar modules and/or arrays of solar modules provided with synchronized movement. According to one exemplary implementation, an illustrative array may comprise a plurality of solar modules. Each solar module may rotate on an axis, and each axis may be in a parallel configuration relative to the other axes. A first rotation mechanism of a solar module may be configured for rotating/pivoting around a first axis/pivot, and be linked to a corresponding rotation mechanism of an adjacent or sequential solar module.



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SYSTEMS AND METHODS INCLUDING FEATURES OF SYNCHRONIZED MOVEMENT ACROSS AN ARRAY OF SOLAR COLLECTORS

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This patent application claims benefit/priority of both U.S. provisional application No. 61/144,615, filed January 14, 2009 entitled POLAR AXES TRACKER ARRANGEMENTS AND TRACKING METHODS FOR SOLAR COLLECTORS and naming Xiao-Dong Xiang as inventor; and U.S. provisional application No. 61/119,855 filed December 4, 2008, entitled POLAR AXES TRACKER ARRANGEMENT FOR SOLAR COLLECTORS and naming Xiao-Dong Xiang as inventor, which are incorporated herein by reference in entirety.

BACKGROUND

Field:

[0002] The present invention relates generally, to solar energy, and more specifically, to systems and methods including features of solar energy collection and/or rotation of arrays of solar collectors.

Description of Related Information:

[0003] Solar panels such as photovoltaic (PV) panels are widely used in residential and commercial solar energy applications. Due to the sun's movement relative to the earth, resulting sun light is incident on the fixed flat PV panel with a different angle at different times of the day, and at different times of the year. This incident angle can reduce the collection efficiency and output power generated by the panels. Since the collection is proportional to the cosine θ , where θ is the angle between the incident sun light beam and the normal of the PV panel, the loss due to this effect is known as cosine loss. In order to increase the collection efficiency, a tracker can be used to mount a PV panel to maintain a position that is near normal to the sun.

[0004] Trackers are more widely used in concentration solar panels, where a large area of optical collectors focus sun light beam on to a small area of a solar receiver which can be PV

cells or a thermal convertor. In order to keep the focus on the target receiver while the sun moves, the tracking system follows movement of the sun, while also remaining in focus.

[0005] There are two types of 2-dimensional tracker systems: azimuth/ elevation tracking and polar (or equatorial) tracking. For a azimuth/elevation tracking system, the mechanical arrangement is simpler. However, since the rotational speeds for both axes are not constant and require constant adjustment at any given position, reliable tracking control schemes are invariably complex and difficult. Indeed, schemes such as these as well as others over which aspects of this disclosure are innovative, need often adopt an active control system, where the sun is actively monitored or a sun-tracking function is actively performed and fed back to control the mechanical system, e.g., for tracking.

[0006] For a polar (or equatorial) tracking system, the two axes are independent. The rotation of the polar axis is constant at 15 degree per hour during the day and the rotational of the declination axis is very slow and simple to track the seasonal movement of the sun. However, mechanical schemes utilized to realize such tracking scheme have a variety of drawbacks. In existing systems, for example, the solar collector body can exert a large torque relative to the polar axis which requires constant rotation during the day. Consequentially, these systems are susceptible to instability from high wind loads which can damage the motor with a reverse torque. For example, when the motor is rigidly connected to several solar collectors having a wind load, the motor can be exposed to the sum of wind load contributed by each solar collector.

[0007] A need exists, therefore, for improved systems, components and techniques for collecting solar energy and/or tracking of the sun.

SUMMARY

[0008] Systems and methods consistent with the innovations herein are directed to configuration and/or tracking features associated with solar collectors.

[0009] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as described. Further features and/or variations may be provided in addition to those set forth herein. For example, the present invention may be directed to various

combinations and subcombinations of the disclosed features and/or combinations and subcombinations of several further features disclosed below in the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a schematic diagram illustrating a side view of a solar module, consistent with aspects related to the innovations herein.

[0011] Figure 2 is a schematic diagram illustrating a side view of a 2-dimensional solar collector module, consistent with aspects related to the innovations herein.

[0012] Figure 3 is a schematic diagram illustrating a front view of the solar collector module from the north, consistent with aspects related to the innovations herein.

[0013] Figure 4 is a schematic diagram illustrating a front view of the solar collector module, consistent with aspects related to the innovations herein.

[0014] Figures 5A-B are schematic diagrams illustrating an array of solar modules driven by one motor assembly, consistent with aspects related to the innovations herein.

[0015] Figure 6 is a schematic diagram illustrating a front view of the solar collector module from the north, consistent with aspects related to the innovations herein.

[0016] Figure 7 is a schematic diagram illustrating a front view of the solar collector module rotated to a morning position, consistent with aspects related to the innovations herein.

[0017] Figures 8A-B are schematic diagrams illustrating an array of solar modules driven by one motor assembly rotated from a morning position to a noon position, consistent with aspects related to the innovations herein.

[0018] Figures 9A-B are schematic diagrams illustrating an array of solar modules driven by one motor assembly rotated from a morning position to a noon position to an evening position, consistent with aspects related to the innovations herein.

[0019] Figures 10A-B are schematic diagrams illustrating a front view of the solar collector module with an alternative polar axis mechanism rotated to a noon and an evening position, consistent with aspects related to the innovations herein.

[0020] Figure 11 is a schematic diagram illustrating a side view of a 2-dimensional solar collector module with an alternative linear actuator declination angle rotation mechanism, consistent with aspects related to the innovations herein.

[0021] Figure 12 is a schematic diagram illustrating a top view (upper) and side view (bottom) of motor/worm gear assembly, consistent with aspects related to the innovations herein.

[0022] Figure 13 is a schematic diagram illustrating a top view of a motor/worm gear assembly with a lead screw driving mechanism, consistent with aspects related to the innovations herein.

[0023] Figure 14 is schematic diagram illustrating a top view of a panel, consistent with aspects related to the innovations herein.

[0024] Figure 15 is a flow chart illustrating a method for synchronizing movement across an array of solar collectors, consistent with aspects related to the innovations herein.

[0025] Figures 16A-C are perspective views of a motor/worm gear assembly, consistent with aspects related to the innovations herein.

[0026] Figures 17 and 18 are perspective views of exemplary solar collectors with worm gear arrangements, consistent with aspects related to the innovations herein.

[0027] Figures 19 and 20 are perspective views of further exemplary solar collectors with worm gear arrangements, consistent with aspects related to the innovations herein.

[0028] Figure 21 illustrates a block diagram of exemplary solar collection system(s) and/or environment(s), consistent with aspects related to the innovations herein.

DETAILED DESCRIPTION OF EXEMPLARY IMPLEMENTATIONS

[0029] Reference will now be made in detail to the invention, examples of which are illustrated in the accompanying drawings. The implementations set forth in the following description do not represent all implementations consistent with the claimed invention. Instead, they are merely some examples consistent with certain aspects related to the invention. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[0030] Consistent with resolution to one or more drawbacks and/or needs regarding existing deployments, systems, methods, and components/computer readable media are presented herein. In one exemplary implementation, an array of solar modules may be provided with synchronized movement along a polar (or other) axis. The array may comprise a plurality of solar modules. Each solar module may rotate on an axis, and each axis may be in parallel configuration relative to the other axes.

[0031] According to exemplary implementations herein, solar collection modules and/or arrays are disclosed. In some exemplary implementations a solar module may be characterized by an axis, wherein the solar module is configured for placement in an array of solar modules such that axes of the array of solar modules are arranged substantially parallel to the axis. For example, a solar module may comprise a first rotational assembly having a first rotational mechanism that rotates/pivots at a first axis/pivot. Further, the first rotational assembly may comprise drive attachment structure that directly or indirectly attaches to an element that transfers a rotational/angular displacement, moment or torque to the first rotational mechanism, link structure configured to link the first rotational mechanism to one or more rotational mechanisms of adjacent or sequential solar module(s) in the array, and panel attachment structure that directly or indirectly attaches to a panel, and by which the second rotational element effects rotation of the panel about the axis. Moreover such modules may, optionally, further comprise a drive mechanism, coupled to a first rotational mechanism, wherein the drive mechanism generates the rotational/angular displacement, moment or torque.

[0032] Additionally, aspects of the innovations herein are directed to arrays of solar modules. In one exemplary implementation, such arrays may comprise a plurality of solar

modules characterized by axes, with each of the axes on one of the solar modules, wherein the axes are arranged substantially parallel to each other. Moreover, each solar module may rotate on an axis and include a first rotational assembly having a first rotational mechanism that rotates/pivots at a first axis/pivot. Further, the first rotational assembly may comprise drive attachment structure that directly or indirectly attaches to an element that transfers a rotational/angular displacement, moment or torque to the first rotational mechanism, link structure configured to link the first rotational mechanism to one or more rotational mechanisms of adjacent or sequential solar module(s) in the array, and panel attachment structure that directly or indirectly attaches to a panel, and by which the second rotational element effects rotation of the panel about the axis. Additionally, such arrays may further comprise a drive mechanism, coupled to a first rotational mechanism, wherein the drive mechanism generates the rotational/angular displacement, moment or torque.

[0033] According to certain exemplary implementations involving two rotational mechanisms per panel, a first rotation mechanism of a solar module may be configured for rotating/pivoting around a first axis/pivot, and be linked to a corresponding rotation mechanism of a sequential solar module. A second rotation mechanism may be configured for rotating/pivoting around a second axis/pivot, and may be linked to the first rotational mechanism with a mechanical linkage. In some implementations, the second rotational mechanism may rotate a panel about the axis, while the first and second rotational pivots remain stationary. Further, the panel may include a solar collector with a plane that rotates in accordance with a plane of sunlight. A driving mechanism may be coupled to at least one of the first rotational mechanisms to provide a rotational/angular force, such as rotational torque, to the rotating mechanisms.

[0034] For example, one implementation of such a solar module comprises a first rotation mechanism of a solar module to pivot around a first pivot, and is linked to a first rotational mechanism of a sequential solar module. A second rotation mechanism pivots around a second pivot, and is linked to the first rotational mechanism with a mechanical linkage. The second rotational mechanism rotates a panel about the axis, while the first and second rotational pivots remain stationary. Further, the panel includes a solar collector with a plane that rotates in accordance with a plane of sunlight. Again, in some implementations, a

driving mechanism may be coupled to at least one of the first rotational mechanisms to generate rotational torque.

[0035] Other exemplary implementations may include one or more further features. For example, the axis may be parallel to a north-south axis of earth rotation, and/or the axis may be tilted by a latitude angle relative to a horizontal plane. Further, the first rotation mechanism may comprise a wheel, the second rotational mechanism may comprise a wheel, and/or the system may further comprise a cable fixed to the first rotational mechanism and separately fixed to the second rotational mechanism, such that torque from the driving mechanism is transferred to the second rotational mechanism without cable movement relative to the first and second rotational mechanisms. Moreover, the second rotational mechanism may comprise a rigid member including one or more hinges and/or further comprise a cable fixed to the first rotational mechanism and separately fixed to the hinge(s) of the second rotational mechanism, such that the torque from the driving mechanism is transferred to the second rotational mechanism without cable movement along the first rotational mechanism. Additionally, the panel may be supported by a bearing at an axis member fixed to the panel and to the second rotational member, the first rotational member may be linked to the driving mechanism with a first cable, the first rotational member may be linked to the sequential first rotational member by a second cable, and/or the driving mechanism may be rigidly coupled to the first rotational member of one of the solar modules. Furthermore, in some implementations, the sequential first rotational member may include a worm gear mechanism, wherein the worm gear mechanism may also prevent torque from transferring back to the driving mechanism. Finally, the plurality of solar modules may be arranged in more than one row.

[0036] Advantageously, the array of solar collectors can be efficiently controlled along a polar axis with a single motor. Additionally, exemplary configurations prevent reverse torque from being transferred back from the array of solar collectors to the single motor.

[0037] In one exemplary implementation, solar collectors are mounted on a solar tracker with at least one (first or polar) rotation axis oriented parallel to Earth's self-rotation axis, that is with a north-south orientation with a tilt angle from horizontal equal to the latitude angle at the location. This polar axis may be supported, for example, by two supports (e.g., legs, columns, piers, etc.) from the ground with pivotal ball bearing or other bearing sleeves to

facilitate the rotation. The rotation of the polar axis is achieved by a first wheel fixed on the high end of rotational polar axial rod, which is driven by a first steel cable anchored and wrapped around the first wheel, and a second wheel a distance away below the first wheel. The second wheel is fixed on a rotational shaft which is supported by a pivotal ball bearing or other bearing sleeves to facilitate the rotation. A gear wheel fixed on the shaft may be driven by a stepping motor and a worm gear to reduce the speed and torque load on the motor, and to prevent backward motion produced by wind or other load. A third wheel mounted on the same axis of the second wheel will in turn drive a second tracker through a second pair of wheel/ steel cable, and later stages operate in a similar manner. In this way, a single set of motor plus worm gear structure and control circuit is used to drive multiple solar trackers to reduce cost of the entire system. Moreover, the use of wheels and a cable, instead of gear wheels and chains (which can also be utilized in the context of aspects of the innovations herein), reduces possible rotational angle error between the first polar axis and subsequent tracker polar axis due to the inelastic extension caused by strain of the chains between modules. It also eliminates the need for lubricant for gears and chains. The cables can be made of materials suited for the application or environment, such as steel, stainless steel, etc. to prevent corrosion. Further, such steel cables may high strength and a specified elasticity to prevent breaking or permanent deformation, often occur in rigid linkage.

[0038] According to some further implementations, panel rotation around the first rotation pivot can be accomplished via worm shaft and worm gearing, e.g., by a pair of worm shaft and worm gear structures. In one exemplary implementation, a worm gear may be located on (or otherwise move) the panel rotation shaft and driven by a worm shaft. Here, for example, the worm shafts in different modules may be connected by pipes and/or flexible connection joints, with one (master) worm shaft being driven, e.g., by a motor and reduction gear box. Advantageous to such implementations, the worm gear rotational mechanism may naturally prevent reverse forces/torque from panel(s) due to wind load from being transferred to the drive mechanism (e.g., motor, etc.) collectively by all modules.

[0039] With regard to one exemplary implementation, the polar rotation axis may be rotated by a constant speed of 15 degree per hour to follow the sun's daily movement with a center position at Solar Noon. The panel is then fixed on to the polar axis to be rotated. As utilized with flat PV (photovoltaic) panel embodiments, this 1-dimensional tracking scheme

is enough to enhance the performance by about 30%, since seasonal declination angle of maximum 23 degree will cost very small cosine loss in average.

[0040] For concentration collector embodiments, a 2-dimensional tracker may be implemented. In these cases, an optional second “seasonal rotation” axis may be added perpendicular to the first axis. The second rotational pivotal support (with bearing) is anchored on the first rotational axis, and the panel is anchored on the seasonal rotational axis. In order to reduce or eliminate the large torque exerted on the polar rotational axis, the collector panel is divided from middle so that the panel can pass through the polar rotational axis while rotating along the seasonal axis (see also, for example, Figures 2, 11 and 14, i.e. split panels to accommodate both seasonal and polar rotations of panels, and associated written description, etc.). With regard to such innovations embodied within Figures 2, 11 and 14 consistent with solar modules and/or arrays disclosed throughout, systems and methods herein may be implemented with the features of these drawings. For example, the panel(s) may be split on a line parallel first axis and have a second axis characterized as being approximately perpendicular to the first axis, wherein the panel is configured to further rotate along the second axis as a function of the declination angle. Such systems and methods may include these or other features shown or described and, as such, the various resulting features. Turning back to the basic 2-dimensional tracker at the beginning of this paragraph, the seasonal axis support and panel is arranged so that the torque of the panel to the polar axis is near zero. The second axis is slowly rotated to track the Sun’s seasonal movement during the year. For 2-dimensional tracker, the polar axis of a large tracker group can be driven by a single motor, while the seasonal axis of each tracker may be driven by individual motor/worm gear mounted on each tracker. The tracker control system can be programmed “chronologically” to position the panel always normal to the sun according to the clock. Here, for example, the correct clock time may be obtained by a GPS signal, by a battery driven electronic clock, etc.

[0041] Figure 1 is a schematic diagram illustrating a side view of a solar module 100, according to one exemplary implementation of the present invention. Solar module 100 may include a beam 1 that provides structural support, and runs along a polar axis 76. The structural beam 1 may be supported pivotally by, for example, two ball bearings 3, 4 with

housings, by other type of bearing sleeves, or the like. A solar energy collector panel 2 is anchored to, and rotates with, the beam 1. One example of a panel is show in Figure 14.

[0042] Referring again to Figure 1, bearing 3 is anchored by its housing to a rotatable hinge 7, which is in turn anchored to a pier 6. Bearing 4 is anchored by its housing to a supporting structure frame 8, which in turn is anchored on a pier 5. The length of frame 8, height on pier 5, can be adjusted to make the polar axis tilt angle equal to latitude angle 77 at the installation location. The latitude angle 77 depends of location (e.g., latitude angle at San Francisco, CA is approximately 37 degrees).

[0043] Figure 2 is a schematic diagram illustrating a side view of a 2-dimensional solar collector module 200, according to a first implementation consistent with aspects related to the innovations herein. A beam 11 on the polar axis 76 can be rotated during the day are arranged and programmed in same fashion as described in the one-dimensional implementation of Figure 11. A pair of ball bearings holed by housings 28 are anchored on the beam 11 to pivotally support a panel 12.

[0044] Further, in some implementations, one ore more unitary or distributed components, such a computing component, a computer, computer readable media, articles of manufacture embodying computer readable media and/or a software program product with code/source code, etc., may be utilized to control movement of the mirrors and of the panels, such as panel 1400, as set forth in more detail in connection with Figure 21.

[0045] Returning to Figure 2, a motor with a worm gear assembly with housing 31 is anchored on the beam 11 and drive a chain gear wheel 32. The chain gear wheel 32 in turn drives a chain 33 with two ends fixed on the two hinges 34, 35 on the frame of the panel 12. A receiver (e.g., a solar thermal or PV receiver) 30 is supported by the structure beams 26 anchored on panel frame 12. The motor is programmed to rotate the solar collector panel 12 and the receiver 30 to form a declination angle 75 with polar axis, and therefore track sun movement during the year.

[0046] Figure 3 is a schematic diagram illustrating a front view 300 of the solar collector module from a direction facing the front of the panel, consistent with a first implementation related to aspects of the innovations herein. Figure 3 also illustrates an exploded view 350 of the wheel 10 assembly shown in the front view 300. As seen in the front view 300 and the

exploded view 350, a first gear wheel 9 may be driven by the motor/ worm gear assembly 14 to drive a flexible linkage element 21, e.g., a cable, chain, or the like. Further, two ends of the flexible linkage 21 may be fixed on the two hinges 12, and 13 on the beam 1.

[0047] Figure 4 is a schematic diagram illustrating a front view of the solar collector module, consistent with aspects related to the innovations herein. Figure 4 illustrates an exemplary single collector module shown rotated to a position towards one end of a range of motion. Here, for example, the position shown may be used to provide increased/maximized collection of solar energy when the sun is at a position to the left in the drawing (e.g., first light, morning, early part of the day, etc.)

[0048] Figures 5A-B are schematic diagrams illustrating an array of solar modules driven by one motor assembly rotated from first to second positions, consistent with aspects related to the innovations herein. Figure 5A illustrates an exemplary multiple collector module arrangement shown rotated to a position towards one end of a range of motion. Here, again, the position shown may be used to provide increased/maximized collection of solar energy when the sun is to the left (e.g., first light, morning, etc.). Figure 5B illustrates an exemplary multiple collector module arrangement shown rotated to a position towards the middle of a range of motion. Here, for example, the position shown may be used to provide increased/maximized collection of solar energy when the sun is straight ahead of the collector/panel (e.g., noon).

[0049] As the gear wheel rotate by motor, the panel rotates along the polar axis as shown in Figure 6 with a single solar module in a noon position 600 compared to Figure 7 with the single solar module in a morning position 700. Moreover, an array of panels linked together rotate along the polar axis, driven by a single motor. Figure 8A shows an array of panels 800 in a morning position compared to Figure 8B which shows the array of panels 850 in a noon position. The motor is programmed to rotate the polar axis by 15 degree per hour during the day to follow the sun's movement during the day. In one exemplary implementation, individual chains 26, 27 run between the solar modules.

[0050] Figures 9A-B are schematic diagrams illustrating an array of solar modules 900 driven by one motor assembly to rotate along a polar axis, according to a third exemplary implementation consistent with aspects related to the innovations herein. Multiple trackers

may be arranged similarly, and a polar axis of each tracker can be driven by only one set of motor/ worm gear. Figure 9B shows a instances of a solar module 950 at a morning position 952, a solar noon position 954, and an afternoon position 956 of a panel (e.g., panel 2 or 12) with declination angle equal to approximately zero.

[0051] Figures 10A-B are schematic diagrams illustrating a front view of a solar collector module 1000, 1050 with an alternative polar axis mechanism rotated to a noon (Figure 10A) and an evening position (Figure 10B), according to one exemplary implementation consistent with aspects related to the innovations herein. In this arrangement, the polar axis is aligned and supported in a similar way as in the other implementations. A supporting structure 78 may have a horizontal beam to support and anchor a motor/ worm gear assembly 36, and a bearing/ chain gear wheel assembly 38. The motor/ worm gear assembly 36 can be similar to the one described in Figures 12 and 13, with a chain gear wheel 37 driven by the worm gear. Such systems may be configured with a chain 39 forming a triangle shape loop with the top fixed on a lever 40. The lever 40 can be fixed (e.g., by a structural element, such as a rectangular fitting hole/rod, etc.) on the end of polar axis to rotate polar axis and panel. Further, the bearing/ chain gear wheel assembly 38 may have two chain gear wheels, with first one drives the chain 39 form the triangular loop to drive lever arm 40 as shown in Figure 10B, and second one drive a second chain to drive the next tracker similar to the configuration shown in Figures 8A and 8B.

[0052] Figure 11 is a schematic diagram illustrating a side view of a 2-dimensional solar collector module 1100 with an alternative linear actuator declination angle rotation mechanism, according to one exemplary implementation consistent with aspects related to the innovations herein. In this arrangement, a lead screw instead of chain is used to rotate the panel to form a declination angle with polar axis. A motor/worm gear assembly 25 is anchored on a beam 42 along the polar axis. A lead screw 37 is driven by the worm gear 24 with its center fixed with a female screw nut over the lead screwing Figure 13. As the worm gear rotates by the motor, the lead screw 37 moves linearly, which in turn pushes the panel 42 to rotate seasonal axis 33 around the pivotal bearing support 28.

[0053] Figure 12 is a schematic diagram illustrating a top view (upper) of a motor/ worm gear assembly 1200, and a side view (bottom) of a motor/ worm gear assembly 1250, according to one exemplary implementation consistent with aspects related to the innovations

herein. Furthermore, Figure 13 is a schematic diagram illustrating a top view of a motor/worm gear assembly 1300 with a lead screw driving mechanism, according to one implementation of the present invention. In Figure 12, a stepping motor with a reduction gear box 19 drives a lead screw 23 through a set of transmission gears 20. The lead screw 23 is pivotally supported by two ball bearings 21,22, and in turn drives a worm gear 24, which is fixed on an axial rod 16. The rod 16 is pivotally supported by two ball bearings 18. The purpose of worm gear is to prevent back movement from the panel weight or wind load through chain wheel gears, i.e. only the turning of the lead screw can make worm gear rotate, the turning of worm gear cannot drive the lead screw to turn. Three chain gear wheels 9, 10, 15 are mounted and fixed on the axial rod 16. The wheel gear 9 drives the chain 11 to rotate the polar axis 1. The gear 10 and 15 are used to gang chain multiple trackers through chains 26, and 27 as shown in Figures 5A-B. The housing for motor/ worm gear drive assembly 25 is fixed on supporting frame 8.

[0054] One example of a panel 1400 is shown in Figure 14. As show in Figure 14, the panel 1400 is supported by a frame 29 and split into two parts to allow the panel 1400 to pass through the polar axis 11 while rotating along the declination axis 33 supported by bearings 28 on a declination angle 75. In one exemplary implementation, the panel 1400 may include an array of mirrors or other reflective elements. The mirrors together form a larger, parabolic aperture, but have been separated into smaller squares and attached to a flat plane of the frame 29. Each mirror can be set at an initial angle taking into account a yearly position of the sun along with how a receiver is positioned above the panel 1400. Each row of mirrors may be rotated by a common angle to compensate for seasonal adjustments of sun light, while the entire frame 29 may be rotated to compensate for daily adjustments of sun light. According to some implementations, a separate motor may control the seasonal movement of rows of mirrors.

[0055] Figure 15 is a flow chart illustrating an exemplary method 1500 for synchronizing movement across an array of solar collectors, according to one exemplary implementation consistent with aspects related to the innovations herein. The method 1500 can be implemented with any one of the systems, such as the systems shown in Figures 5A-B, Figures 8A-B, and Figures 9A-B.

[0056] In accordance with the exemplary methods consistent with Figure 15, an array of solar modules may be linked by a first rotation mechanism of each module. The first rotation mechanisms are rotated 1520 around a first pivot, to drive a second rotational mechanism of each solar module around a second pivot. A panel of each solar module is rotated 1530 with the second rotational mechanism such that a plane of the panel rotates in accordance with a plane of sun light. In one exemplary implementation, the rotation maintains optimal exposure to sun light for maximum energy transfer. A rotational torque is generated 1540 for the array of solar modules with a driving mechanism coupled to at least one of the first rotational mechanisms.

[0057] Figures 16A-C are schematic diagrams illustrating views of a motor/ worm assembly 1600, according to one exemplary implementation consistent with aspects related to the innovations herein. Figure 16A shows a perspective view of the motor/ worm assembly 1600. A first steel chain wraps around a first wheel 1602a and a second steel chain wraps around a second wheel 1602b. The wheels 1602a,b are separated by a worm gear slave drive box 1604. Figure 16B shows a side view of the motor/ worm assembly 1600. From this angle a worm gear wheel 1652 and a worm gear rod 1654 are shown. In general, the first wheel 1602a provides input torque to turn the second wheel 1602b with an output torque. In one example, the input torque is provided by a motor or a wheel from an adjacent solar module. The output torque is provided to another wheel from another adjacent solar module. However, reverse torque (from e.g., wind) is blocked from transferring in the opposite direction.

[0058] Figure 16C shows a perspective view of the motor/ worm assembly 1600 with an open panel to show inner components. The inner components operate according to a drive sequence that provides rotational torque from a first wheel 1602a to a second wheel 1602b. More specifically, an input axis 1671 drives a gear wheel 1672, the gear wheel 1672 drives the gear wheel 1673, the gear wheel 1673 drives the gear wheel 1674, the gear wheel 1674 drives the gear wheel 1675, the gear wheel 1675 drives the angled gear wheel 1676, the angled gear wheel 1676 drives the angled gear wheel 1677, the angled gear wheel 1677 drives the worm rod 1678, the worm rod 1678 drives the worm gear wheel 1679, and the worm gear wheel 1679 drives an output axis 1680. Consequentially, input torque is transferred to output torque.

[0059] Figures 17 and 18 are perspective views of exemplary solar collectors with worm gear arrangements, consistent with aspects related to the innovations herein. Figure 17 is a expanded view of a first exemplary implementation of a worm gear assembly 301, 302, 303, 304 (regarding which, with respect to the gearing per se, Figures 16A-C are one example) in relation to the collector panels 305, which are shown in these drawings as reflector panels by way of illustration, not limitation.

[0060] Figure 18 is a diagram illustrating a side view of an exemplary worm gear assembly, according to one implementation consistent with aspects related to the innovations herein. In Figure 18, a motor with a worm gear assembly and housing 301 is positioned relative to the various panels 305. The motor 301 may be used to rotate a rod 302 having threaded regions 306 at locations to engage rotational elements 304, e.g., wheels, etc., via complimentary worm gear engaging portions. A panel or receiver (e.g., a solar thermal or PV receiver, etc.) 305 may be coupled to the rotational elements 304. As such, the motor 301 may be programmed to rotate all of the interconnected panels or receivers simultaneously to track the sun's movement. Moreover, the mechanical configuration of such worm gear assemblies is simple, and the components are straightforward and readily available as well as inexpensive relative to the structures of comparable tracking assemblies. For example, the rod portions 302 may be formed of simple tubing with sections of threaded regions 306 attached in short sections to longer stretches of existing/basic/inexpensive rod or tubing members. Further, [XD/Rong, please add any other advantages]

[0061] Figures 19 and 20 are perspective views of exemplary solar collectors with worm gear arrangements, consistent with aspects related to the innovations herein. Figure 19 is a expanded view of another exemplary implementation of a worm gear assemblies 401, 402, 403, 404, 405 (regarding which, with respect to the gearing per se, Figures 16A-C are one example) in relation to collector panels or receivers 408, which are shown in these drawings as reflector panels by way of illustration, not limitation. The worm gear assemblies 401, 402, 403, 404, 405 illustrated in Figures 19 and 20 may be consistent with those shown and described in connection with Figures 17 and 18. Figure 19 illustrates their interconnectivity with the panels 408 via additional rotating member 405, 407 and flexible linkage elements 406, such as cables, chains, etc.

[0062] Figure 20 is a diagram illustrating a detailed view of the exemplary worm gear assembly of Figure 19, according to one implementation consistent with aspects related to the innovations herein. In Figure 20, a motor with a worm gear assembly and housing 401 is positioned relative to the various panels 408. As with the above implementations, the motor 401 may be used to rotate a rod 402 having threaded regions 403 at locations to engage first rotational elements 405, e.g., wheels, etc., via complimentary worm gear engaging portions. Additionally, flexible linkage elements 406 or other rotational moment translating elements are then coupled to the first rotational elements 405, and second rotational elements 407 are coupled to the flexible linkage elements 406 or rotational moment translating elements. Further, then, panels or receivers (e.g., a solar thermal or PV receiver, etc.) 408 may be coupled to the second rotational elements 407. In accordance with such configuration(s), the motor 401 may be programmed to rotate all of the interconnected panels or receivers simultaneously to track the sun's movement. Here, the rotational elements 405, 407 and flexible linkage 406 or rotational moment translating elements provide for direct translation of necessary impulses to move the panels, e.g., across spans or distances, without requiring any further or complex elements or calculations, as with existing systems. Moreover, as set forth above, the mechanical configuration of such worm gear assemblies is simple, and the components are straightforward and readily available as well as inexpensive relative to the structures of comparable tracking assemblies.

[0063] Figure 21 illustrates a block diagram of an exemplary solar collection system in accordance with one or more implementations of the innovations herein. Referring to Figure 21, the solar collection system may comprise a solar field 120 including solar collectors 100 and a controller 170 and, optionally, one or more elements of external systems 130. The controller may include one or more computing components, systems and/or environments 180 that perform, facilitate or coordinate control of the collectors. As explained in more detail below, such computing elements may take the form of one or more local computing structures that embody and perform a full implementation of the features and functionality herein or these elements may be distributed with one or more controller(s) 170 serving to coordinate the distributed processing functionality. Further, the controller 170 is not necessarily in close physical proximity to the collectors 100, though is shown in the drawings as being associated with solar field 20. Solar collection system may also include one or more optional external devices or systems 130, which may embody the relevant computing

components, systems and/or environments 180 or may simply contain elements of the computing environment that work together with other computing components in distributed arrangements to realize the functionality, methods and/or innovations herein.

[0064] With regard to computing components and software embodying the inventions herein, such as the tracking and collection methods, the innovations herein may be implemented/operated consistent with numerous general purpose or special purpose computing system environments or configurations. Various exemplary computing systems, environments, and/or configurations that may be suitable for use with the innovations herein may include, but are not limited to, personal computers, servers or server computing devices such as routing/connectivity components, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, smart phones, consumer electronic devices, network PCs, other existing computer platforms, distributed computing environments that include one or more of the above systems or devices, etc.

[0065] The invention may be described in the general context of computer-executable instructions, such as program modules, being executed by a computer, computing component, etc. In general, program modules may include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. The invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote computer storage media including memory storage devices.

[0066] Computing component/environment 180 may also include one or more type of computer readable media. Computer readable media can be any available media that is resident on, associable with, or can be accessed by computing component/environment 180. By way of example, and not limitation, computer readable media may comprise computer storage media and communication media. Computer storage media includes volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic tape, magnetic disk storage or other magnetic

storage devices, or any other medium which can be used to store the desired information and can accessed by computing component 800. Communication media may comprise computer readable instructions, data structures, program modules or other data embodying the functionality herein. Further, communication media may include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. Combinations of the any of the above are also included within the scope of computer readable media.

[0067] In the present description, the terms component, module, device, etc. may refer to any type of logical or functional process or blocks that may be implemented in a variety of ways. For example, the functions of various blocks can be combined with one another into any other number of modules. Each module can be implemented as a software program stored on a tangible memory (e.g., random access memory, read only memory, CD-ROM memory, hard disk drive) to be read by a central processing unit to implement the functions of the innovations herein. Or, the modules can comprise programming instructions transmitted to a general purpose computer or to processing/graphics hardware via a transmission carrier wave. Also, the modules can be implemented as hardware logic circuitry implementing the functions encompassed by the innovations herein. Finally, the modules can be implemented using special purpose instructions (SIMD instructions), field programmable logic arrays or any mix thereof which provides the desired level performance and cost.

[0068] As disclosed herein, implementations and features of the invention may be implemented through computer-hardware, software and/or firmware. For example, the systems and methods disclosed herein may be embodied in various forms including, for example, a data processor, such as a computer that also includes a database, digital electronic circuitry, firmware, software, or in combinations of them. Further, while some of the disclosed implementations describe components such as software, systems and methods consistent with the innovations herein may be implemented with any combination of hardware, software and/or firmware. Moreover, the above-noted features and other aspects and principles of the innovations herein may be implemented in various environments. Such environments and related applications may be specially constructed for performing the various processes and operations according to the invention or they may include a general-purpose computer or computing platform selectively activated or reconfigured by code to

provide the necessary functionality. The processes disclosed herein are not inherently related to any particular computer, network, architecture, environment, or other apparatus, and may be implemented by a suitable combination of hardware, software, and/or firmware. For example, various general-purpose machines may be used with programs written in accordance with teachings of the invention, or it may be more convenient to construct a specialized apparatus or system to perform the required methods and techniques.

[0069] Aspects of the method and system described herein, such as the logic, may be implemented as functionality programmed into any of a variety of circuitry, including programmable logic devices (“PLDs”), such as field programmable gate arrays (“FPGAs”), programmable array logic (“PAL”) devices, electrically programmable logic and memory devices and standard cell-based devices, as well as application specific integrated circuits. Some other possibilities for implementing aspects include: memory devices, microcontrollers with memory (such as EEPROM), embedded microprocessors, firmware, software, etc. Furthermore, aspects may be embodied in microprocessors having software-based circuit emulation, discrete logic (sequential and combinatorial), custom devices, fuzzy (neural) logic, quantum devices, and hybrids of any of the above device types. The underlying device technologies may be provided in a variety of component types, e.g., metal-oxide semiconductor field-effect transistor (“MOSFET”) technologies like complementary metal-oxide semiconductor (“CMOS”), bipolar technologies like emitter-coupled logic (“ECL”), polymer technologies (e.g., silicon-conjugated polymer and metal-conjugated polymer-metal structures), mixed analog and digital, and so on.

[0070] It should also be noted that the various logic and/or functions disclosed herein may be enabled using any number of combinations of hardware, firmware, and/or as data and/or instructions embodied in various machine-readable or computer-readable media, in terms of their behavioral, register transfer, logic component, and/or other characteristics. Computer-readable media in which such formatted data and/or instructions may be embodied include, but are not limited to, non-volatile storage media in various forms (e.g., optical, magnetic or semiconductor storage media) and carrier waves that may be used to transfer such formatted data and/or instructions through wireless, optical, or wired signaling media or any combination thereof. Examples of transfers of such formatted data and/or instructions by carrier waves include, but are not limited to, transfers (uploads, downloads, e-mail, etc.) over

the Internet and/or other computer networks via one or more data transfer protocols (e.g., HTTP, FTP, SMTP, and so on).

[0071] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise,” “comprising,” and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in a sense of “including, but not limited to.” Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words “herein,” “hereunder,” “above,” “below,” and words of similar import refer to this application as a whole and not to any particular portions of this application. When the word “or” is used in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

[0072] Although certain exemplary implementations of the present innovations have been specifically described herein, it will be apparent to those skilled in the art to which the invention pertains that variations and modifications of the various implementations shown and described herein may be made without departing from the spirit and scope of innovations consistent with this disclosure. Accordingly, it is intended that the innovations be limited only to the extent required by the appended claims and the applicable rules of law.

In the Claims:

1. A solar module characterized by an axis, wherein the solar module is configured for placement in an array of solar modules such that axes of the array of solar modules are arranged substantially parallel to the axis, the solar module comprising:

a first rotational assembly having a first rotational mechanism that rotates/pivots at a first axis/pivot, the first rotational assembly comprising:

drive attachment structure that directly or indirectly attaches to an element that transfers a rotational/angular displacement, moment or torque to the first rotational mechanism;

link structure configured to link the first rotational mechanism to one or more rotational mechanisms of adjacent or sequential solar module(s) in the array; and

panel attachment structure that directly or indirectly attaches to a panel, and by which the second rotational element effects rotation of the panel about the axis.

2. The module of claim 1 further comprising a drive mechanism, coupled to a first rotational mechanism, wherein the drive mechanism generates the rotational/angular displacement, moment or torque.

3. The solar module of claim 1 wherein the first pivot is stationary.

4. The solar module of claim 1 further comprising a second rotational mechanism that rotates/pivots at a second pivot and is linked to the first rotational mechanism with a linkage.

5. The solar module of claim 4 wherein the first pivot and the second pivot are stationary.

6. An array of solar modules, the array comprising:

a plurality of solar modules characterized by axes, with each of the axes on one of the solar modules, wherein the axes are arranged substantially parallel to each other, and wherein each solar module rotates on an axis and includes:

a first rotational assembly having a first rotational mechanism that rotates/pivots at a first axis/pivot, the first rotational assembly comprising:

drive attachment structure that directly or indirectly attaches to an element that transfers a rotational/angular displacement, moment or torque to the first rotational mechanism;

link structure configured to link the first rotational mechanism to one or more rotational mechanisms of adjacent or sequential solar module(s) in the array; and

panel attachment structure that directly or indirectly attaches to a panel, and by which the second rotational element effects rotation of the panel about the axis.

7. The array of claim 6 wherein the first pivot is stationary.
8. The array of claim 6 further comprising a second rotational mechanism that rotates/pivots at a second pivot and is linked to the first rotational mechanism with a linkage.
9. The array of claim 8 wherein the first pivot and the second pivot are stationary.
10. A solar module characterized by an axis, wherein the solar module is configured for placement in an array of solar modules such that axes of the array of solar modules are arranged substantially parallel to the axis, the solar module comprising:

a first rotational assembling including a first rotational mechanism that rotates/pivots at a first pivot, the first rotational assembly comprising:

drive attachment structure with a component that directly or indirectly attaches to an element that transfers a rotational/angular displacement, moment or torque to the first rotational mechanism;

link structure to link the first rotational mechanism to one or more rotational mechanisms of adjacent or sequential solar module(s) in the array; and

a second rotational mechanism that rotates/pivots at a second pivot and is linked to the first rotational mechanism with a linkage, wherein the second rotational mechanism includes panel attachment structure with a component that directly or indirectly attaches to a panel, and by which the second rotational element effects rotation of the panel about the axis.

11. The solar module of claim 10 wherein the first pivot and the second pivot are stationary.

12. An array of solar modules, the array comprising:

a plurality of solar modules characterized by axes, with each of the axes on one of the solar modules, wherein the axes are arranged substantially parallel to each other, and wherein each solar module rotates on an axis and includes:

a first rotational mechanism that rotates/pivots at a first pivot and is linked to one or more first rotational mechanisms of adjacent or sequential solar modules,

a second rotational mechanism that rotates/pivots at a second pivot and is linked to the first rotational mechanism with a linkage, wherein the second rotational mechanism is configured to rotate a panel about the axis, and wherein the first pivot and the second pivot are stationary;
and

a drive mechanism, coupled to a first rotational mechanism, wherein the drive mechanism generates a rotational/angular displacement, moment or torque.

13. Any of the modules or arrays of claims 1-12 wherein each panel comprises a solar collector characterized by a plane that rotates in accordance with a plane of sunlight.

14. Any of the module(s) or array(s) of claims 1-13 wherein the rotational/angular displacement, moment or torque is provided via a worm gear assembly.

15. The module(s) or array(s) of claim 14 further comprising rod, tubing or other linearly rotating structure to link rotational elements between panels for translating the rotational/angular displacement, moment or torque.

16. An array of solar modules with synchronized movement, the array comprising:
- a plurality of solar modules, each solar module rotating on an axis, each axis in parallel configuration relative to other axes, each solar module including:
 - a first rotation mechanism of a solar module pivots around a first pivot, linked to a first rotational mechanism of a sequential solar module,
 - a second rotation mechanism pivots a second pivot, linked to the first rotational mechanism with a mechanical linkage, the second rotational mechanism to rotate a panel about the axis, wherein the first and second rotational pivots are stationary, the panel comprising a solar collector with a plane that rotates in accordance with a plane of sun light; and
 - a drive mechanism, coupled to at least one of the first rotational mechanisms, the driving mechanism to generate a rotational/angular displacement, moment or torque.
17. The array of claim 16, wherein the axis is parallel to a north-south axis of earth rotation.
18. The array of claim 17, wherein the axis is tilted by a latitude angle relative to a horizontal plane.
19. The array of claim 16, wherein the first rotation mechanism comprises a wheel.
20. The array of claim 19, wherein the second rotational mechanism comprises a wheel and further comprising a cable fixed to the first rotational mechanism and separately fixed to the second rotational mechanism, such that torque from the driving mechanism is transferred to the second rotational mechanism without cable movement relative to the first and second rotational mechanisms.
21. The array of claim 19, wherein the second rotational mechanism comprises a rigid member with at least two hinges and further comprising a cable fixed to the first rotational mechanism and separately fixed to the hinges of the second rotational mechanism, such that

the torque from the driving mechanism is transferred to the second rotational mechanism without cable movement along the first rotational mechanism.

22. The array of claim 16, wherein the panel is supported by a bearing at an axis member fixed to the panel and to the second rotational member.

23. The array of claim 16, wherein the first rotational member is linked to the driving mechanism with a first cable, and to the sequential first rotational member by a second cable.

24. The array of claim 16, wherein the driving mechanism is rigidly coupled to the first rotational member of one of the solar modules.

25. The array of claim 16, wherein the sequential first rotational member includes a worm gear mechanism, wherein the worm gear mechanism prevents torque from transferring back to the driving mechanism.

26. The array of claim 16, wherein the plurality of solar modules are arranged in more than one row.

27. A method of synchronizing movement in an array of solar modules, the method comprising:

rotating each solar module of a plurality of solar modules on an axis, each axis in parallel configuration relative to other axes, including:

rotating/pivoting a first rotational mechanism around a first axis/pivot, linked to a first rotational mechanism of a sequential solar module, and

rotating/pivoting a second rotational mechanism, linked to the first rotational mechanism, around a second axis/pivot, the second rotational mechanism causing a panel to rotate about the axis, wherein the first and second rotational pivots are stationary; and

generating a rotational/angular displacement, moment or torque with a driving mechanism coupled to at least one of the first rotational mechanisms.

28. The method of claim 27 further comprising rotating the panel/solar collector along a plane such that the plane of the panel/solar collector rotates in accordance with a plane of sunlight.
29. The method of claim 27, wherein the axis is parallel to a north-south axis of earth rotation.
30. The method of claim 27, wherein the axis is tilted by a latitude angle relative to a horizontal plane.
31. The method of claim 27, wherein the first rotation mechanism comprises a wheel.
32. The method of claim 31, wherein the second rotational mechanism comprises a wheel and further comprising a cable fixed to the first rotational mechanism and separately fixed to the second rotational mechanism, such that torque from the driving mechanism is transferred to the second rotational mechanism without cable movement relative to the first and second rotational mechanisms.
33. The method of claim 31, wherein the second rotational mechanism comprises a rigid member with at least two hinges and further comprising a cable fixed to the first rotational mechanism and separately fixed to the hinges of the second rotational mechanism, such that the torque from the driving mechanism is transferred to the second rotational mechanism without cable movement along the first rotational mechanism.
34. The method of claim 27, wherein the panel is supported by a bearing at an axis member fixed to the panel and to the second rotational member.
35. The method of claim 27, wherein the first rotational member is linked to the driving mechanism with a first cable, and to the sequential first rotational member by a second cable.
36. The method of claim 27, wherein the driving mechanism is rigidly coupled to the first rotational member of one of the solar modules.
37. The method of claim 27, wherein the sequential first rotational member includes a worm gear mechanism, wherein the worm gear mechanism prevents torque from transferring back to the driving mechanism.

38. The method of claim 27, wherein the plurality of solar modules are arranged in more than one row.

39. An array of solar modules with synchronized movement, the array comprising:

a plurality of solar modules, each solar module rotating on an axis, each axis in parallel configuration relative to other axes, each solar module including:

a first wheel of a solar module to pivot around a first pivot, the first wheel receiving rotational torque from a driver, and

a second wheel, linked to the first wheel, the second wheel to transfer rotational torque to a sequential solar collector, wherein the first and second wheels are linked to an arm member rigidly attached to rotate a panel, the panel comprising a solar collector with a plane that rotates in accordance with a plane of sun light;

a driving mechanism, coupled to at least one of the first wheels of one of the solar module, the driving mechanism to generate a rotational/angular displacement, moment or torque.

40. One or more of the modules or arrays of any of claims 1-24 wherein the panel is split on a line parallel first axis and has a second axis characterized as being approximately perpendicular to the first axis, wherein the panel is configured to further rotate along the second axis as a function of the declination angle.

41. A system comprising:

a solar collection assembly including a module, panel or array consistent with one or more of the features of any of claims 1 through 26, 39, 40, or features of the present specification, drawings and/or claims; and

a computing component configured to process instructions including instruction related to movement of the panel(s)/solar collector(s), wherein the instructions include instructions consistent with one or more features recited in any of claims 27 through 38 or set forth in the present specification, drawings and/or claims.

42. At least one computer readable medium containing or configured to execute computer-readable instructions relating to movement of solar panel(s)/collector(s), the computer-readable instructions comprising instructions for:

processing information or performing actions consistent with one or more steps or features recited in any of claims 1 through 41, or features of the present specification, drawings and/or claims.

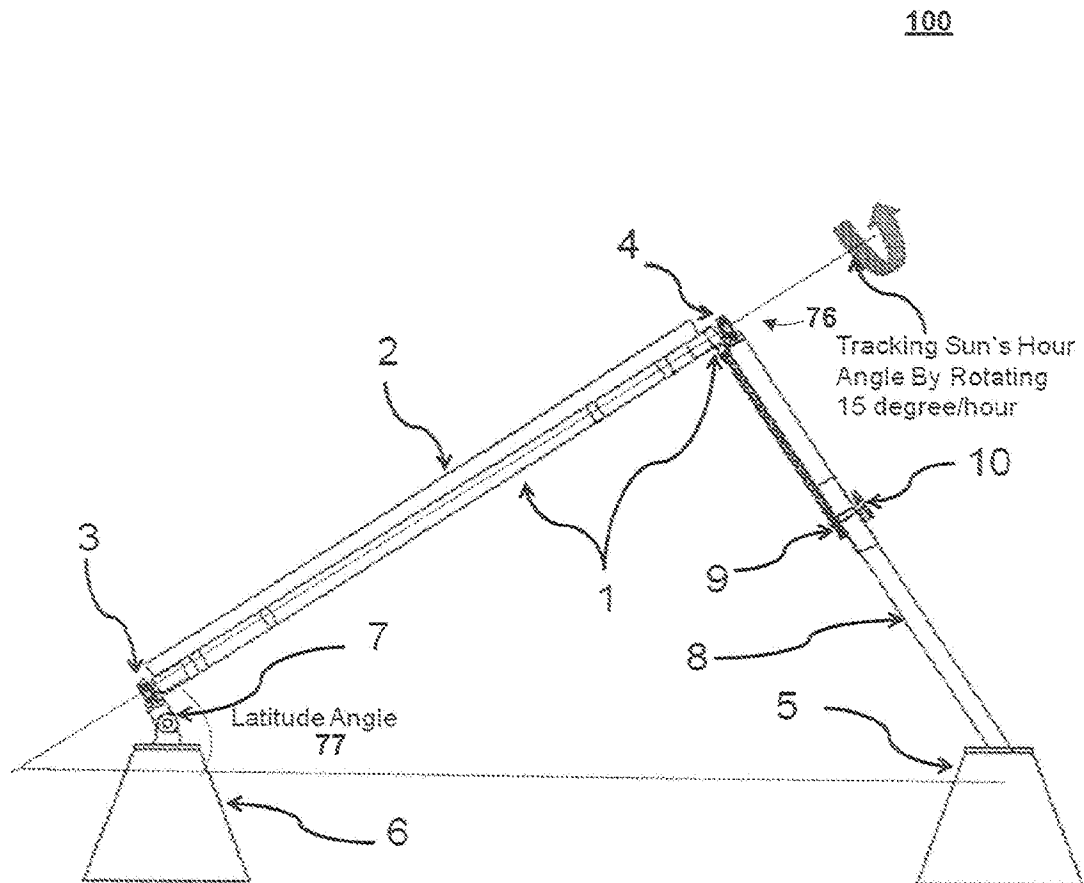
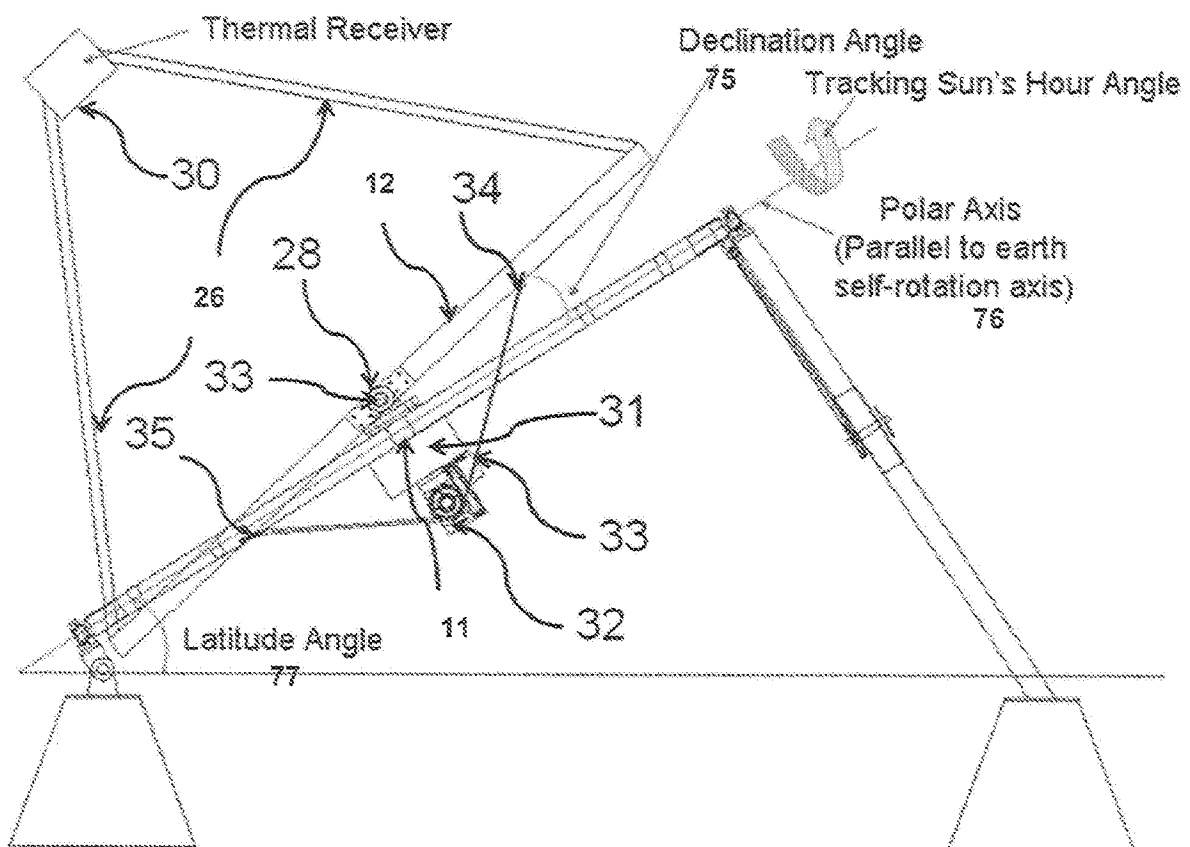


FIG. 1

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200**FIG. 2**

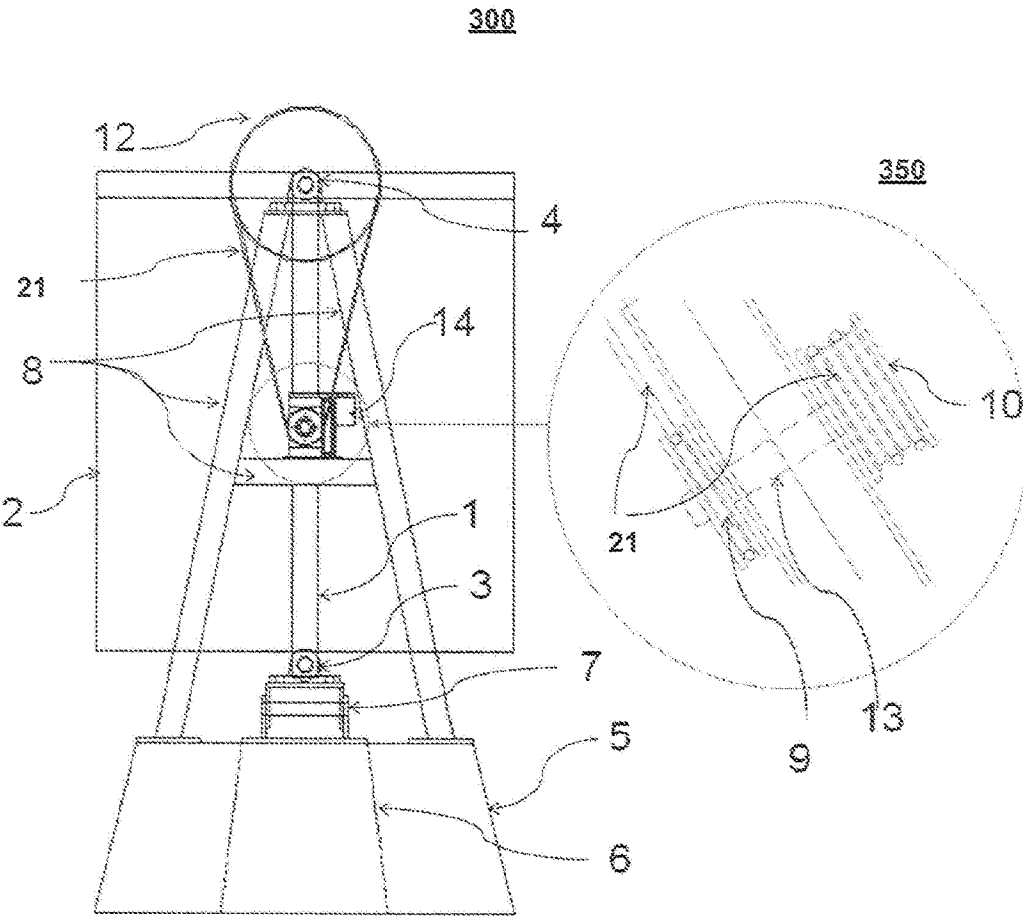


FIG. 3

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400

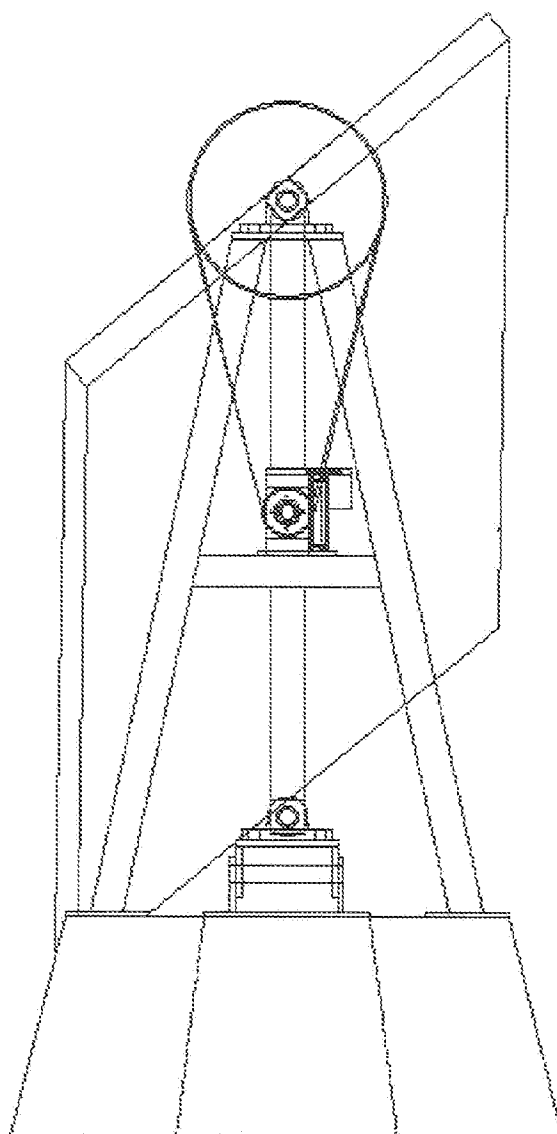


FIG. 4

500

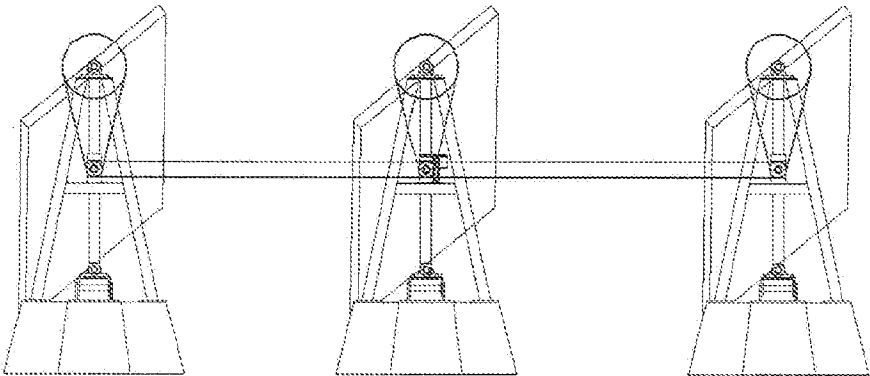


FIG. 5A

550

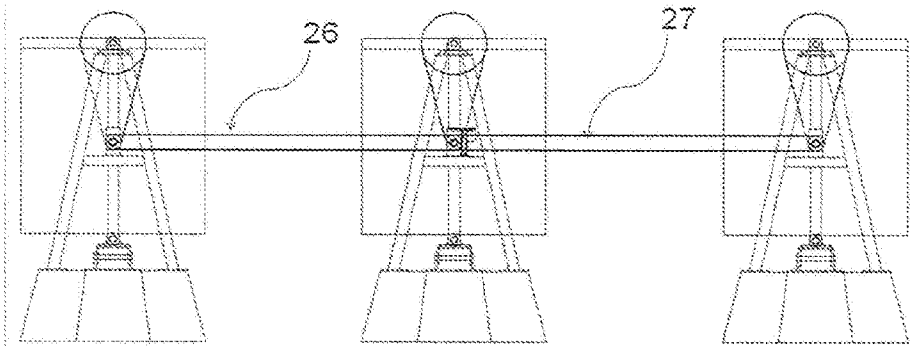


FIG. 5B

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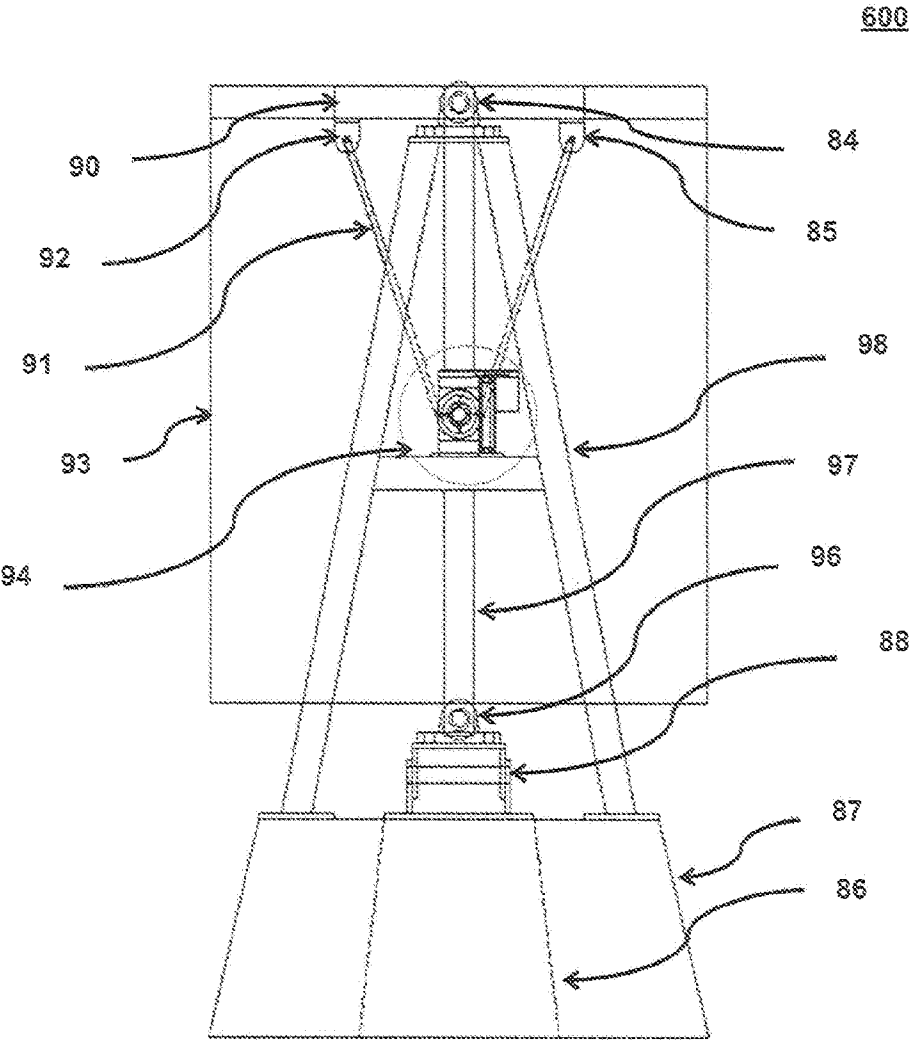


FIG. 6

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700

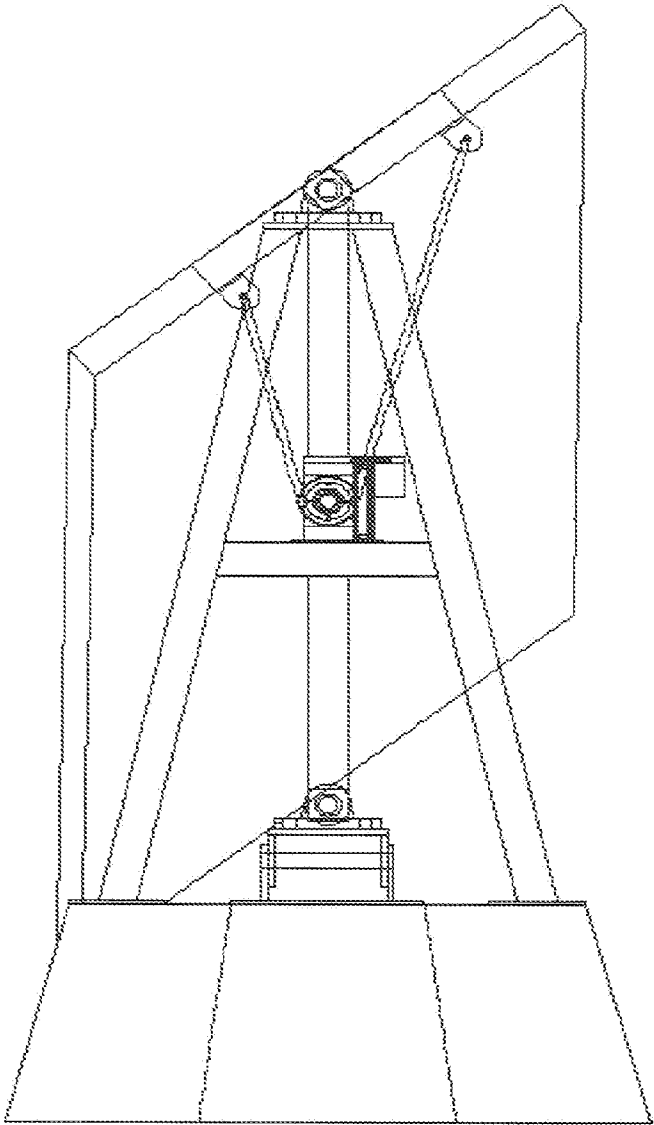


FIG. 7

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800

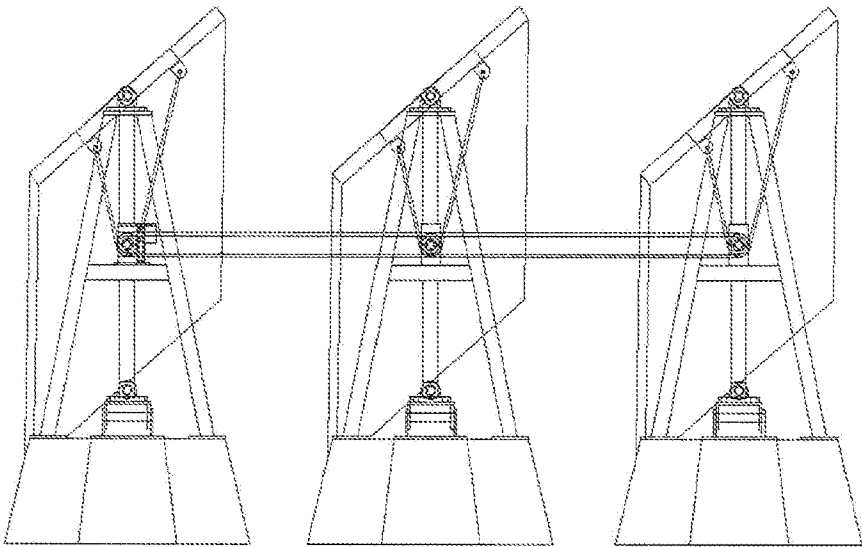


FIG. 8A

850

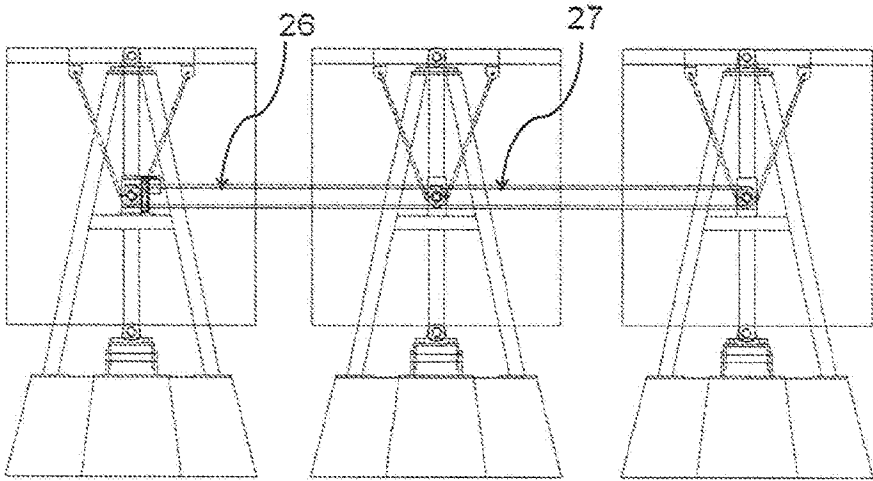


FIG. 8B

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200

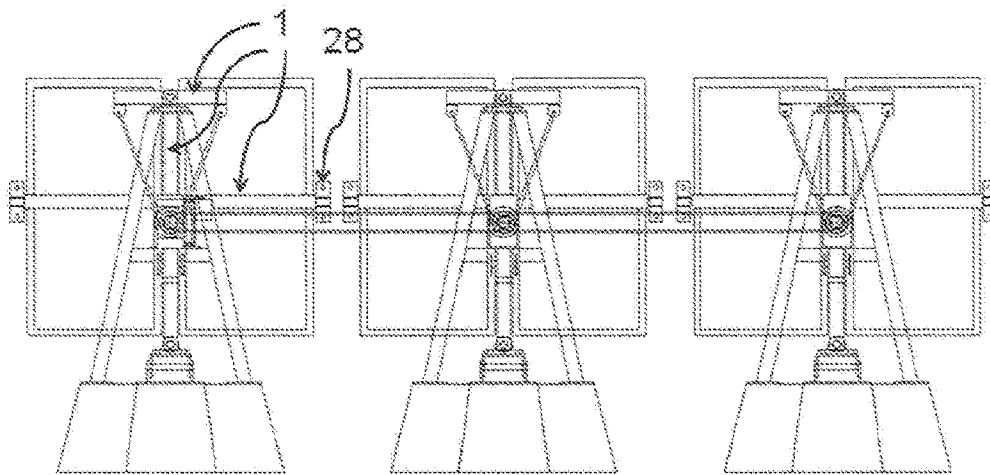


FIG. 9A

950

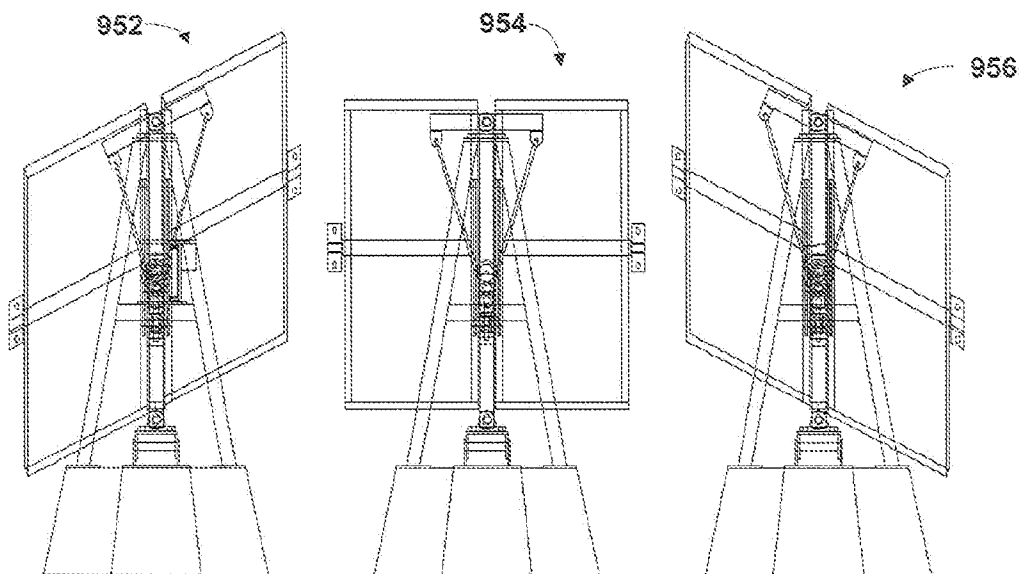


FIG. 9B

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1000

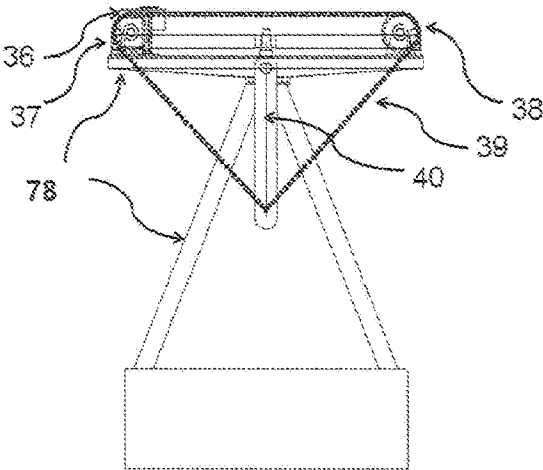


FIG. 10A

1050

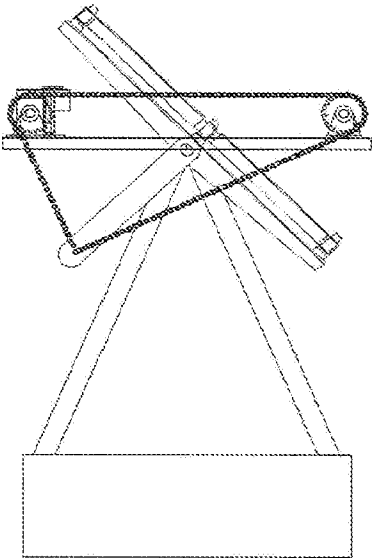


FIG. 10B

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1100

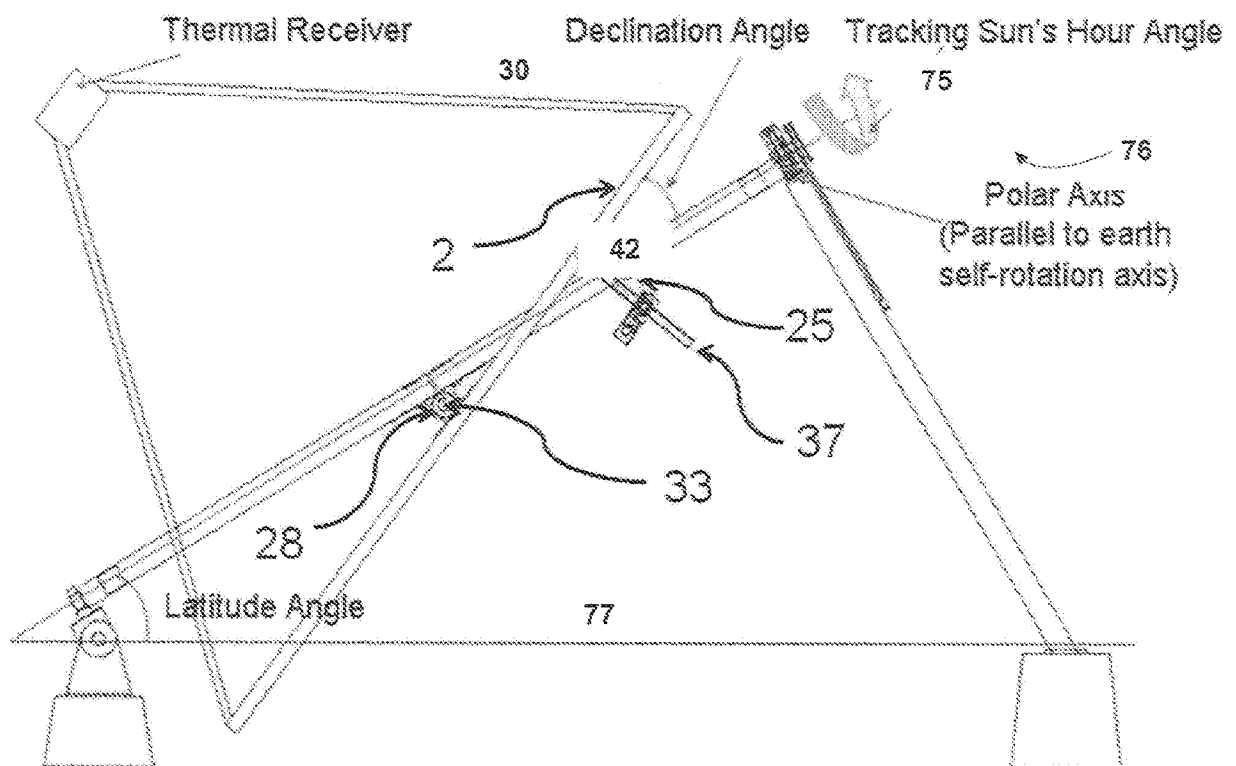
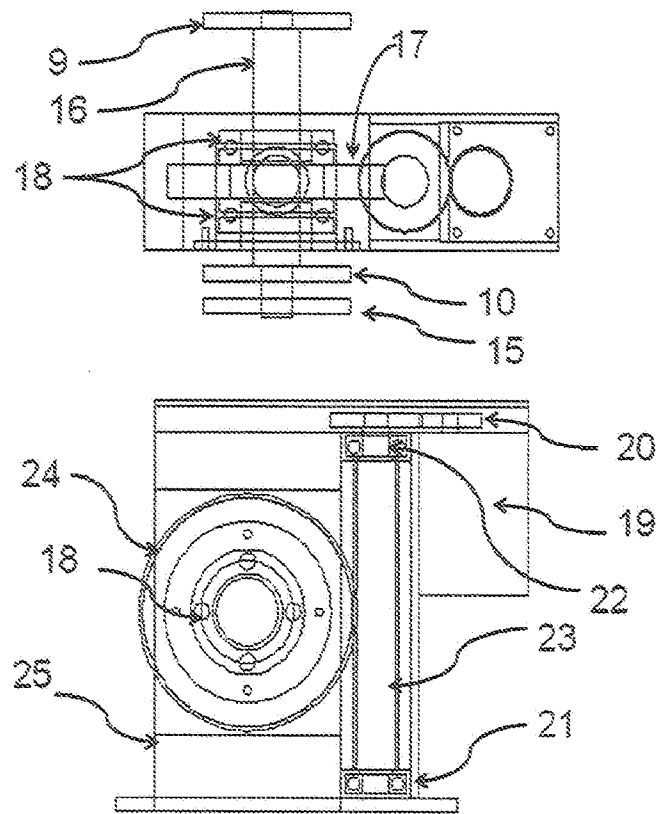


FIG. 11

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1200



1250

FIG. 12

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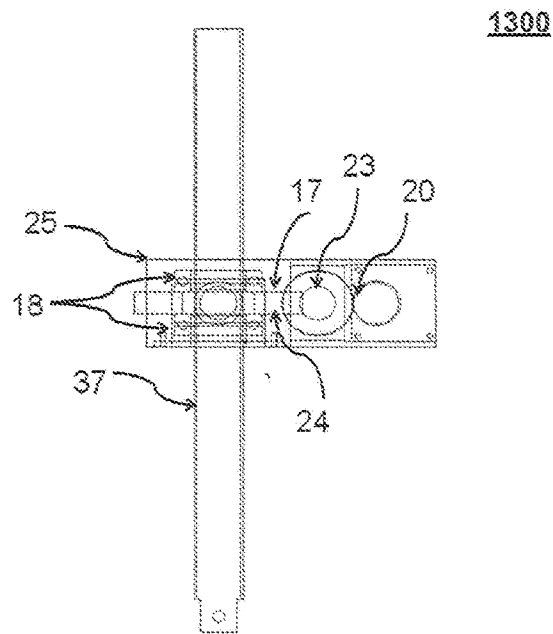


FIG. 13

1400

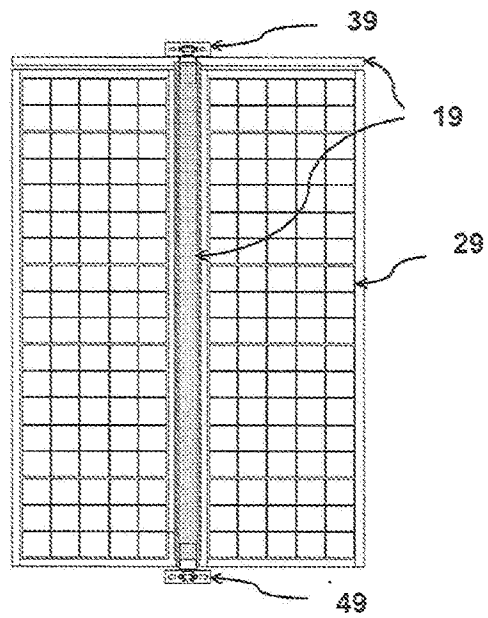


FIG. 14

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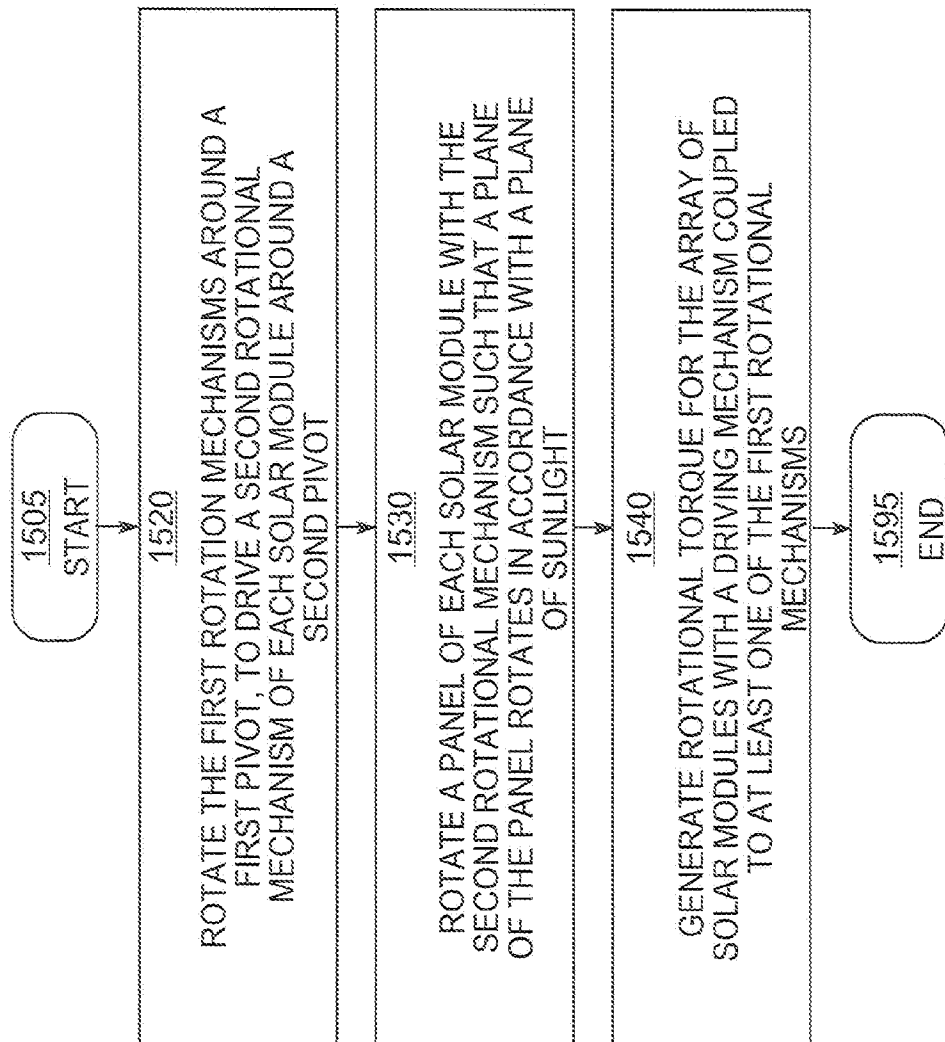


FIG. 15

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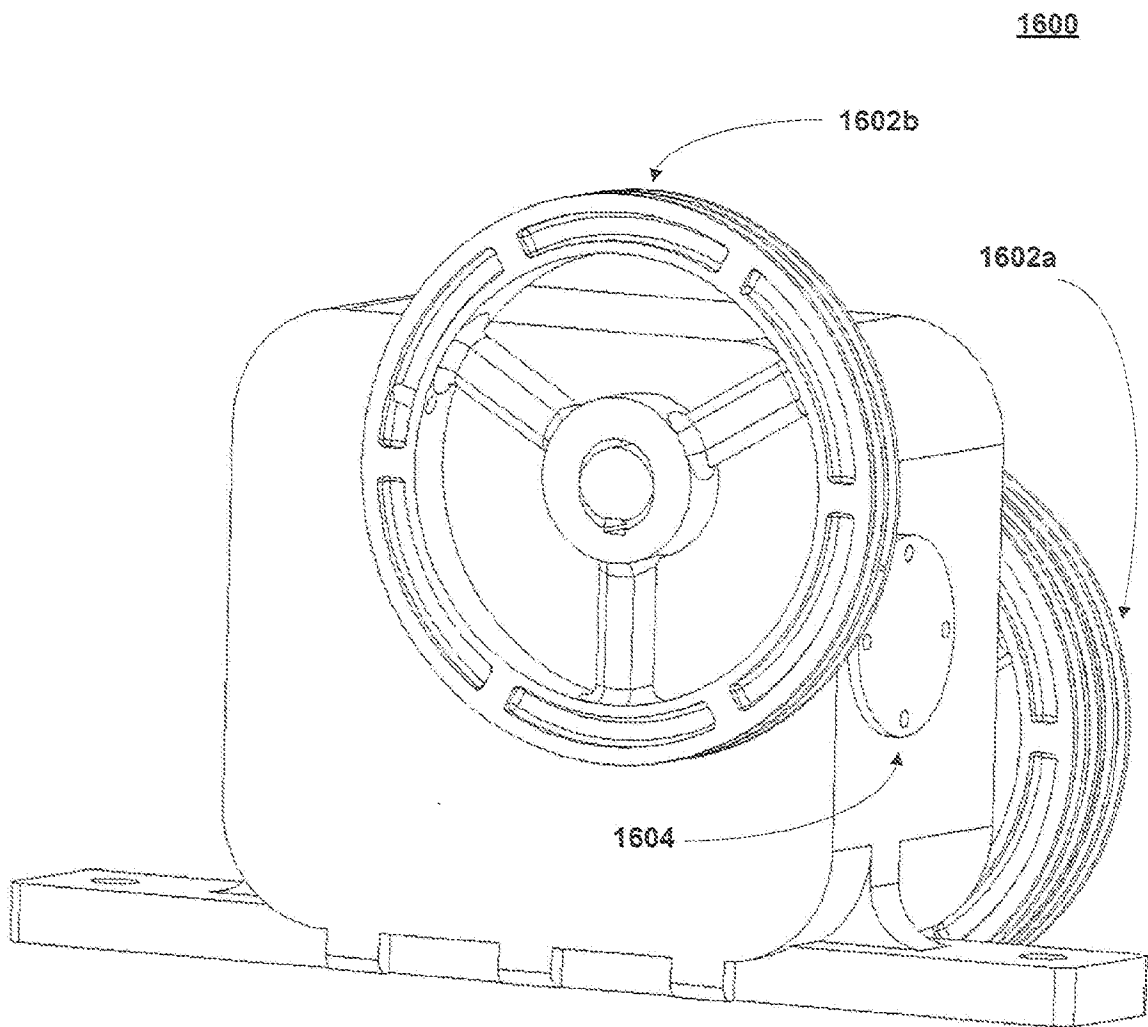


FIG. 16A

1600

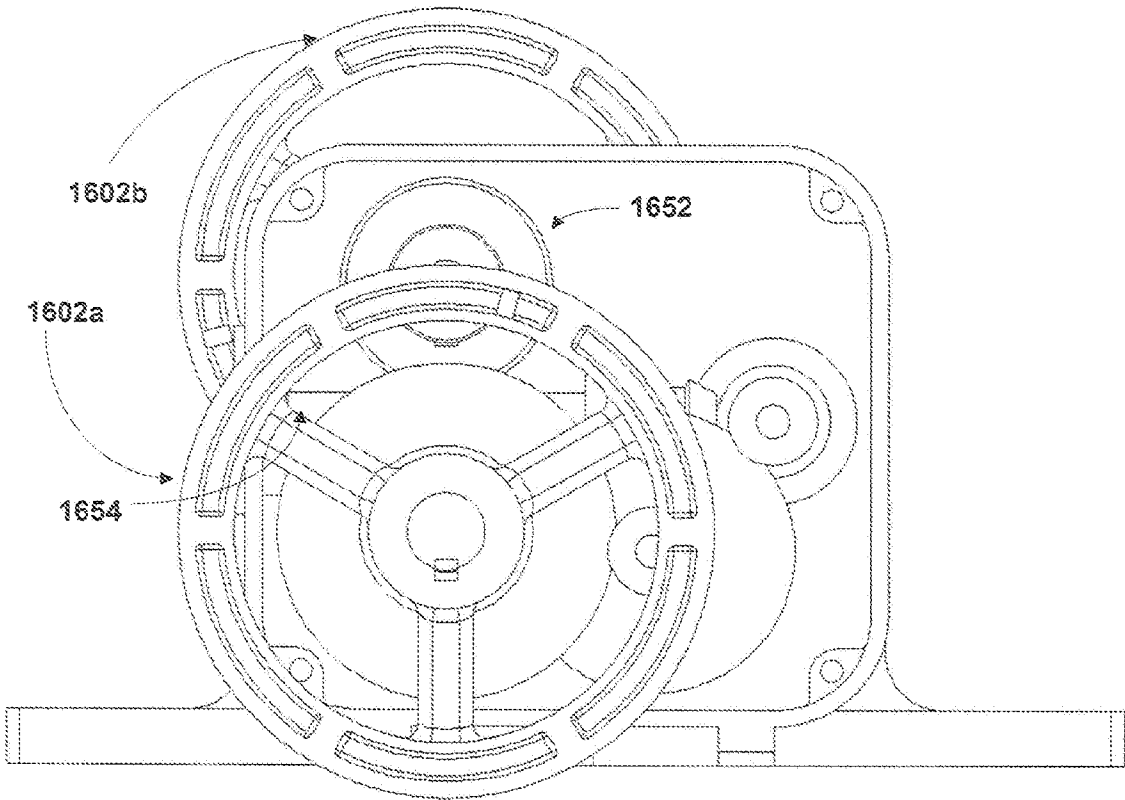


FIG. 16B

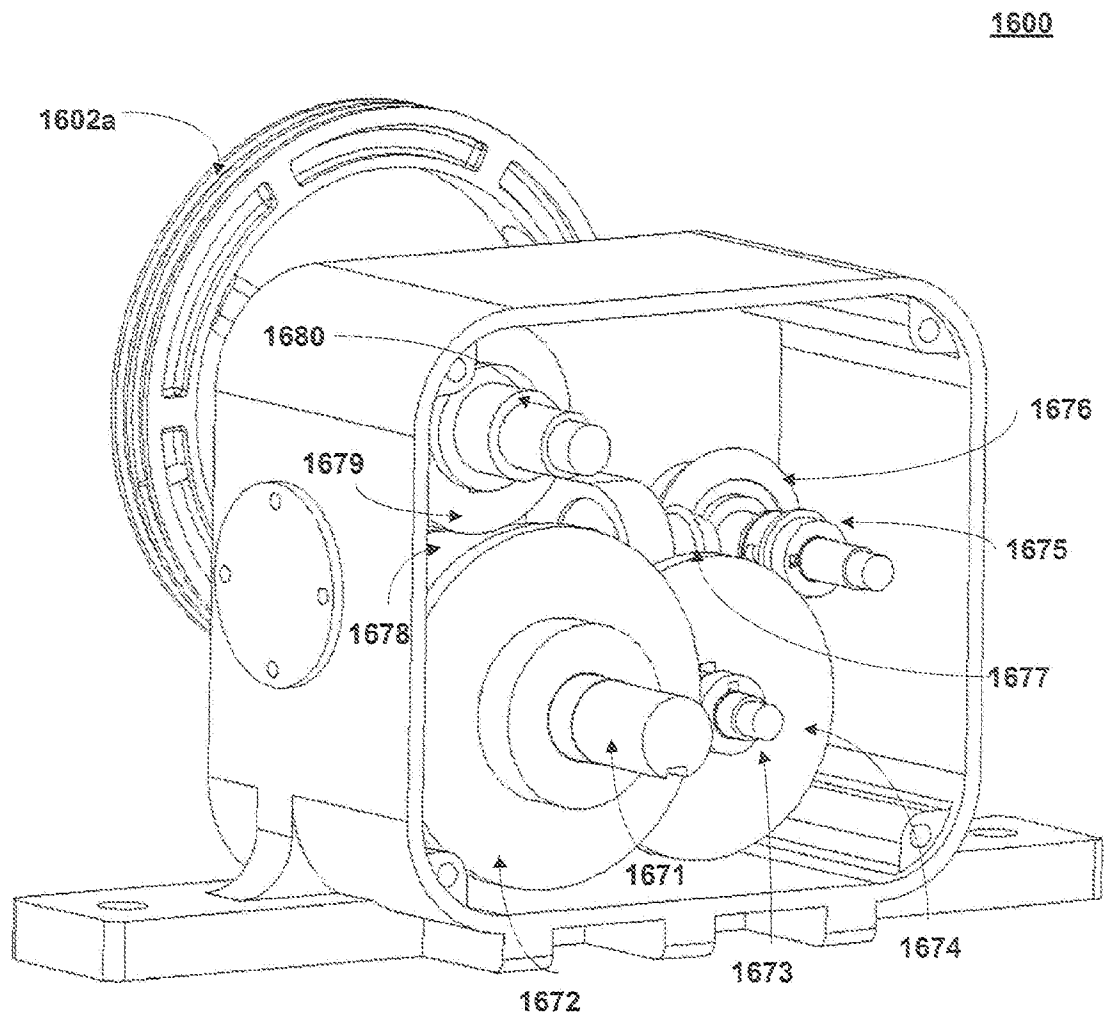


FIG. 16C

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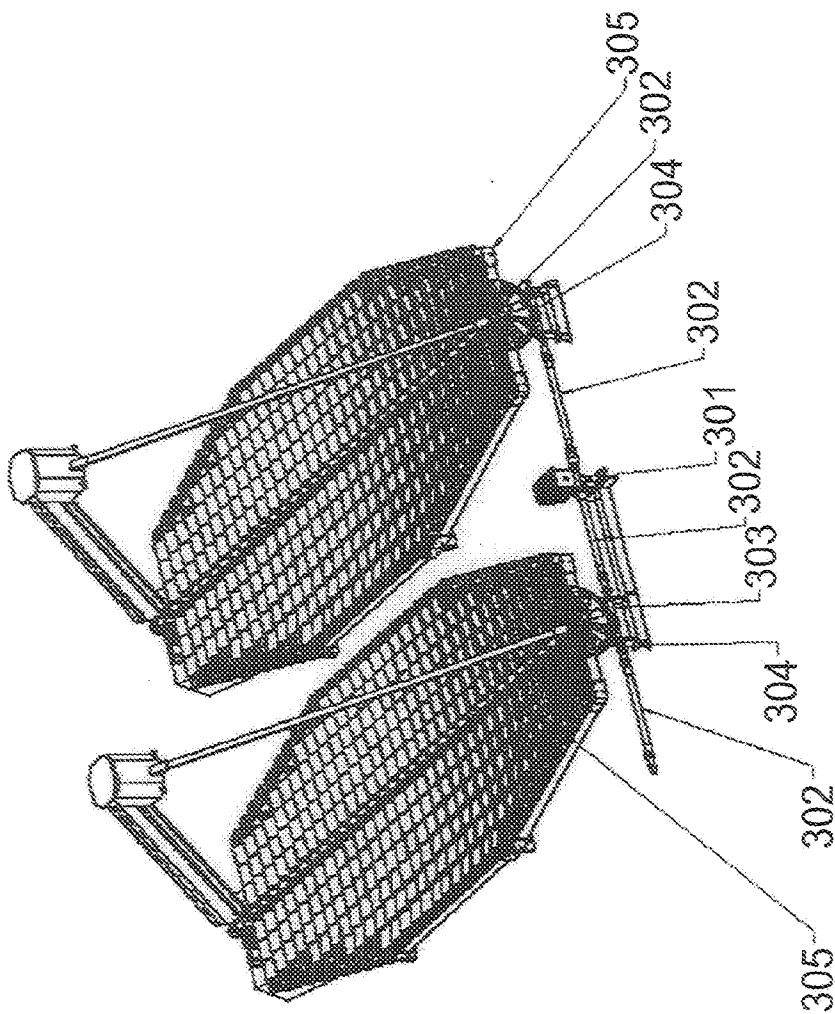


FIG. 17

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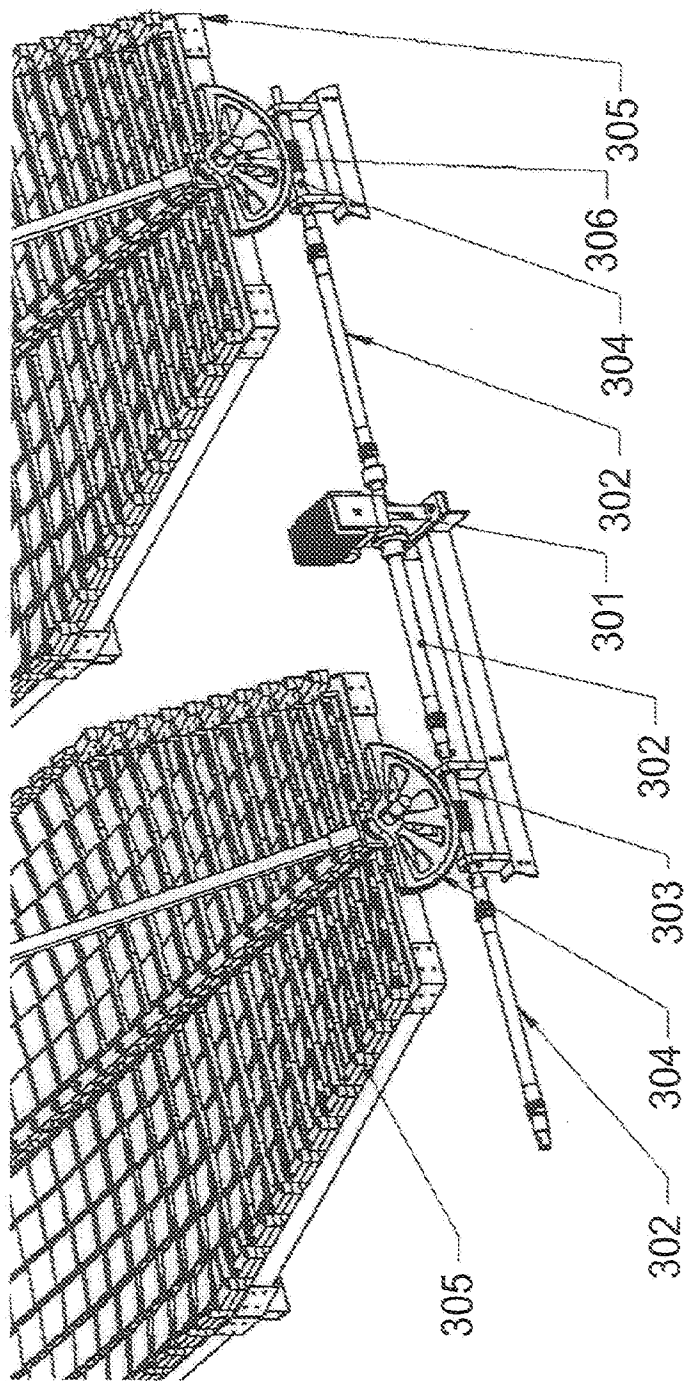
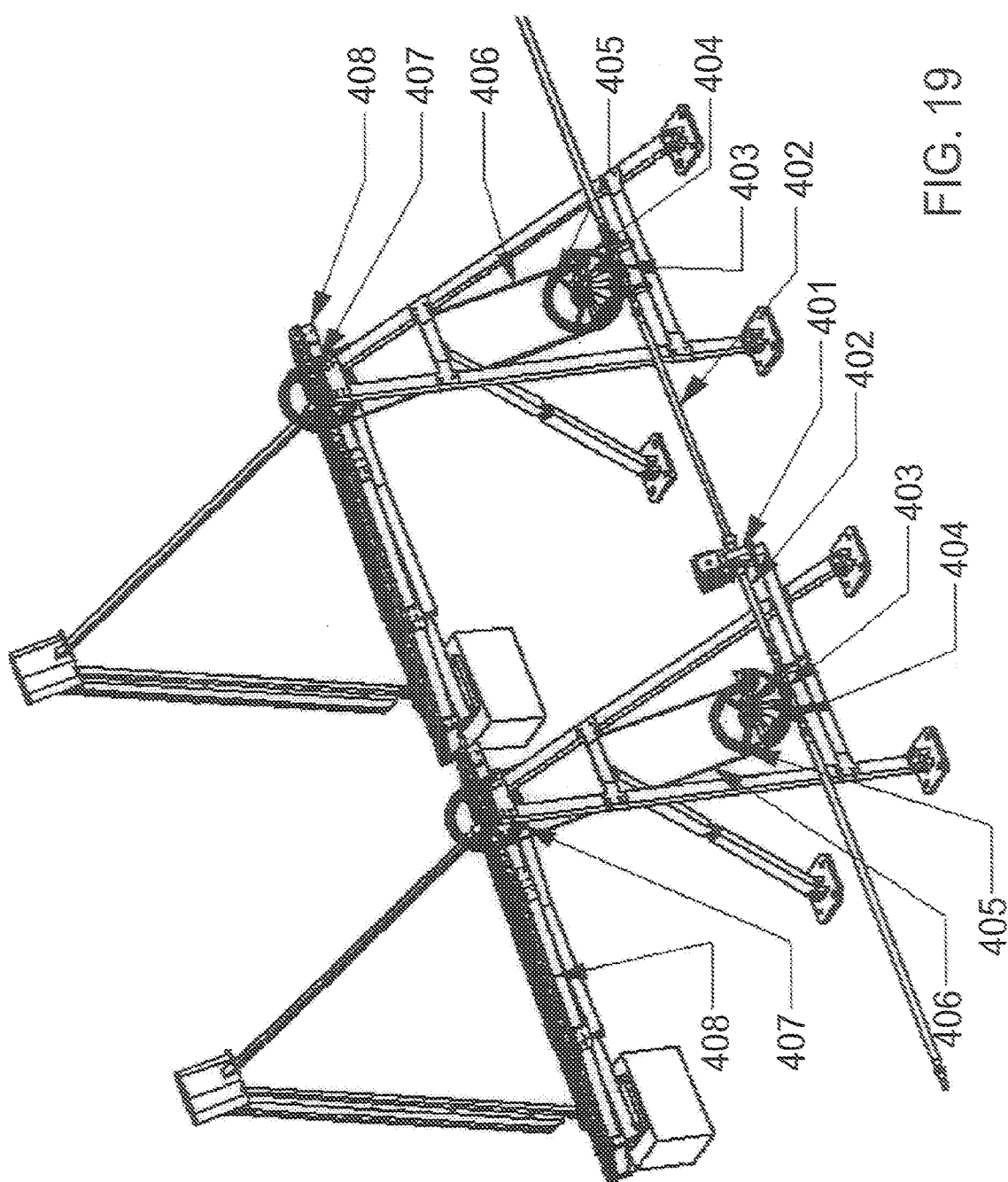


FIG. 18

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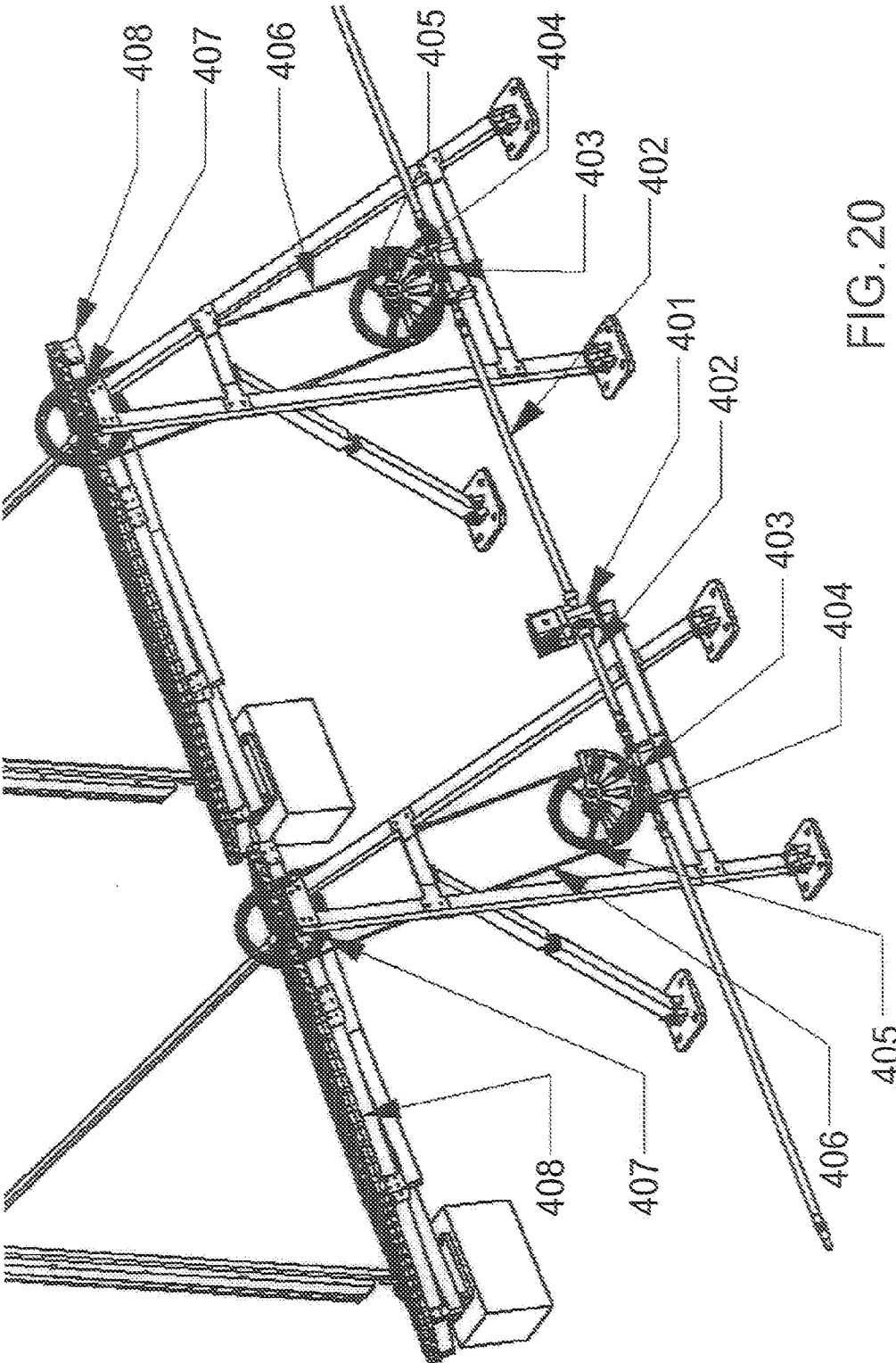


FIG. 20

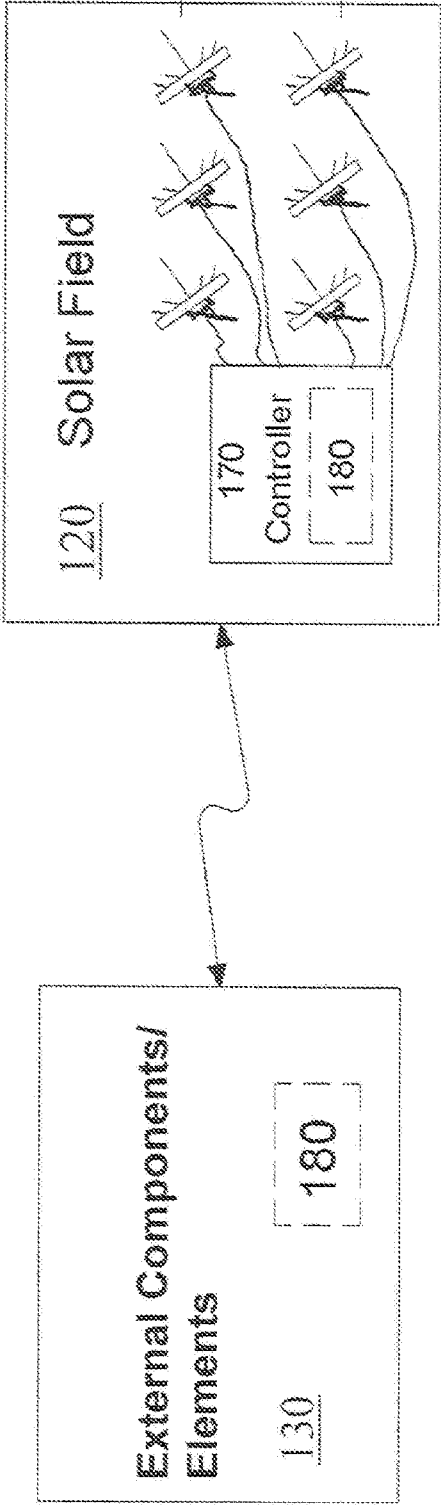


Fig. 21