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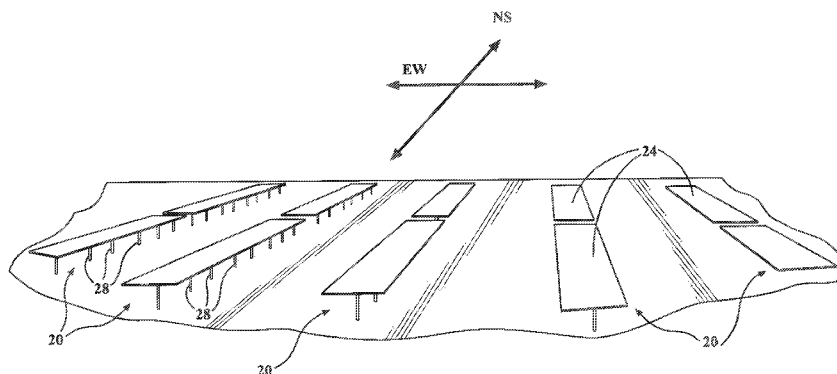


FIG. 1

(57) Abstract: The solar field includes a plurality of the single axis solar tracker assemblies with solar panels, torque tubes and drive mechanisms. The solar field further includes a controller which is configured to receive a wind speed and is in communication with the drive mechanisms. The controller is also configured to operate the drive mechanisms to rotate the solar panels about the axes to follow the sun in response to the wind speed being below a first predetermined threshold wind speed and to operate the drive mechanisms to rotate the solar panels about the axes into stowing orientations wherein the solar panels are angled relative to a horizontal plane in a range of 10 to 30 degrees in response to the wind speed being above a second predetermined threshold wind speeds.



WO 2017/007983 A1

SOLAR PANEL ASSEMBLY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This PCT Patent Application claims the benefit of U.S. Provisional Patent Application Serial Number 62/190,325 filed on July 9, 2015 entitled "Solar Panel Assembly," the entire disclosure of the application being considered part of the disclosure of this application and hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The subject invention relates to solar panel assemblies for harnessing solar rays to produce electricity.

2. Related Art

[0003] Solar fields typically include multiple, spaced apart rows of solar panel assemblies which are spaced from one another. In some solar panel assemblies, the solar panels are oriented at fixed (i.e., non-adjustable) angles. In other solar panel assemblies, commonly known as single axis solar trackers, the solar panels are all coupled with a longitudinally extending torque tube such that rotation of the torque tube about an axis rotates the solar panels. During the day, the torque tube is controllably rotated to allow the solar panels to track the sun through the sky, thereby increasing the amount of energy harnessed by the solar panels. Typically, the single axis solar trackers are all mechanically connected with one another via a single drive mechanism which is adapted to simultaneously rotate all of the solar panels in the solar field

[0004] For single axis solar trackers, during particularly windy conditions, it is common practice to orient all of the solar panels into horizontal orientations with the solar panels facing directly vertically upward.

SUMMARY OF THE INVENTION AND ADVANTAGES

[0005] One aspect of the present invention is related to a solar field including a plurality of single axis solar tracker assemblies that are spaced apart from one another. Each of the single axis solar tracker assemblies includes a plurality of solar panels that are operably supported by a torque tube and includes a drive mechanism that is operably connected with the torque tube for rotating the torque tube and the solar panels about an axis. The solar field further includes a controller which is configured to receive a wind speed and is in communication with the drive mechanisms of the single axis solar tracker assemblies. The controller is configured to operate the drive mechanisms to rotate the solar panels about the axes to follow the sun in response to the wind speed being below a first predetermined threshold wind speed and to operate the drive mechanisms to rotate the solar panels about the axes into stowing orientations wherein the solar panels are angled relative to a horizontal plane in a range of 10 to 30 degrees in response to the wind speed being above a second predetermined threshold wind speeds.

[0006] According to another aspect of the present invention, the solar field further includes a wind speed sensor for determining the wind speed and in communication with the controller.

[0007] According to yet another aspect of the present invention, the drive mechanisms include slew drive adapters.

[0008] According to still another aspect of the present invention, the plurality of solar tracker assemblies are separated into first and second groups that are separated from one another in a first direction and wherein in the stowing orientations, all of the solar panels of the single axis solar tracker assemblies in the first group are angled relative to the horizontal plane in a first rotational direction and all of the solar panels of the single axis solar tracker

assemblies in the second group are angled relative to the horizontal plane in a second rotational direction that is opposite of the first rotational direction.

[0009] According to yet a further aspect of the present invention, each of the first and second groups has an outer solar tracker assembly that is furthest from the other of the first and second groups and an inner solar tracker assembly that is nearest the other of the first and second groups, and when in the stowing orientations, the outer solar tracker assemblies are angled at a greater magnitude relative to the horizontal plane than the inner solar tracker assemblies.

[0010] According to still a further aspect of the present invention, when in the stowing orientations, the solar panels of adjacent single axis solar tracker assemblies are angled relative to the horizontal plane in opposite rotational directions.

[0011] According to another aspect of the present invention, the second predetermined threshold wind speed is greater than the first predetermined threshold wind speed.

[0012] According to yet another aspect of the present invention, the controller is further configured to operate the drive mechanisms to hold the solar panels stationary in response to the wind speed being between the first and second predetermined threshold wind speeds.

[0013] According to still another aspect of the present invention, the first predetermined threshold wind speed is approximately 35 mph, and the second predetermined threshold wind speed is approximately 50 mph.

[0014] Another aspect of the present invention is related to a solar assembly which includes a plurality of pillars that are spaced from one another and extend in a vertical direction to respective upper attachment ends. A torque tube is supported by the upper attachment ends of the pillars and is rotatable about an axis. A plurality of solar panels are

supported by the torque tubes and are rotatable about the axis with the torque tube. A drive mechanism including a slew drive adapter is operably connected with the torque tube for rotating the torque tube and the plurality of solar panels about the axis. The solar assembly further includes a controller which is configured to receive a wind speed and is in communication with the drive mechanism. The controller is configured to operate the drive mechanism to rotate the solar panels about the axis to follow the sun in response to the wind speed being below a first predetermined threshold wind speed and to operate the drive mechanism to rotate the solar panels about the axis into stowing orientations wherein the solar panels are angled relative to a horizontal plane in a range of 10 to 30 degrees in response to the wind speed being above a second predetermined threshold wind speed.

[0015] According to another aspect of the present invention, the solar assembly further includes a wind speed sensor for measuring the wind speed and in communication with the controller.

[0016] According to yet another aspect of the present invention, the second predetermined threshold wind speed is greater than the first predetermined threshold wind speed.

[0017] According to still another aspect of the present invention, the controller is further configured to operate the drive mechanism to hold the solar panels stationary in response to the wind speeds being between the first and second predetermined threshold wind speeds.

[0018] According to a further aspect of the present invention, the first predetermined threshold wind speed is approximately 35 mph, and the second predetermined threshold wind speed is approximately 50 mph.

[0019] A further aspect of the present invention is related to a method of operating a solar field that includes a plurality of single axis solar tracker assemblies. The solar trackers

are spaced from one another, and each solar tracker assembly has a plurality of solar panels that are rotatable about an axis independently of the solar panels of the other solar tracker assemblies. The method includes the step of determining a wind speed. In response to the determined wind speed being less than a first predetermined threshold wind speed, the method continues with the step of rotating the solar panels of the solar tracker assemblies about the axes to follow the sun. In response to the determined wind speed being greater than a second predetermined threshold wind speed, the method proceeds with the step of rotating the solar panels of the solar trackers into stowing orientations wherein the solar panels are angled in a range of 10 to 30 degrees relative to a horizontal plane.

[0020] According to another aspect of the present invention, the second predetermined threshold wind speed is greater than the first predetermined threshold wind speed.

[0021] According to yet another aspect of the present invention, the method further includes the step of, in response to the determined wind speed being between the first and second predetermined threshold wind speeds, locking the solar panels against rotation about the axes.

[0022] According to still another aspect of the present invention, the solar tracker assemblies are divided into first and second groups that are separated from one another in the first direction and, in the stowing orientations, all of the solar panels of the solar tracker assemblies in the first group are angled relative to the horizontal plane in a first rotational direction and all of the solar panels of the solar tracker assemblies in the second group are angled relative to the horizontal plane in a second rotational direction that is opposite of the first rotational direction.

[0023] According to a further aspect of the present invention, each of the first and second groups has an outer solar tracker assembly that is furthest from the other of the first

and second groups and an inner solar tracker assembly that is nearest the other of the first and second groups, and in the stowing orientations, the outer solar tracker assemblies are angled at a greater angle relative to the horizontal plane than the inner solar tracker assemblies.

[0024] According to yet a further aspect of the present invention, when the solar panels are in the stowing orientations, the solar panels of adjacent solar tracker assemblies are angled relative to the horizontal plane in opposite rotational directions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] These and other features and advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0026] Figure 1 is a perspective elevation view of an exemplary embodiment of a solar field;

[0027] Figure 2 is a perspective elevation view of one single axis solar tracker assembly of the solar field of Figure 1;

[0028] Figure 3 is a fragmentary and enlarged view of a portion of Figure 2;

[0029] Figure 4 is a perspective and fragmentary view of a drive mechanism of the single axis solar tracker assembly of Figure 2;

[0030] Figure 5a is a schematic showing various forces acting on the single axis solar tracker assembly during windy conditions;

[0031] Figure 5b is a table showing force measurements for an exemplary single axis solar tracker assembly taken at 105 mph with the solar panels being angled at different orientations relative to a horizontal plane;

[0032] Figure 6 is a front schematic view of the solar field of Figure 1 in a first stowing configuration;

[0033] Figure 7 is a front schematic view of the solar field of Figure 1 in a second stowing configuration;

[0034] Figure 8 is a front schematic view of the solar field of Figure 1 in a third stowing configuration; and

[0035] Figure 9 is a flow chart showing an exemplary embodiment of a method of operating a solar field.

DETAILED DESCRIPTION OF THE ENABLING EMBODIMENT

[0036] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, a solar field including a plurality of single axis solar tracker assemblies 20 is generally shown in Figure 1. The single axis solar tracker assemblies 20 are spaced from one another in a first direction (hereinafter referred to as an “east-west direction”). As shown in Figures 2 and 3, each of the single axis solar tracker assemblies 20 includes a torque tube 22 which extends along an axis in a second direction (hereinafter referred to as a “north-south direction”) that is generally transverse to the east-west direction. A plurality of solar panels 24 are operatively connected with the torque tube 22 and are rotatable about the axis in response to rotation of the torque tube 22. This allows the solar panels 24 to track the sun as it moves across the sky from east to west during each day, thereby maximizing the amount of solar exposure for the solar panels 24 and the amount of electricity generated by the solar panels 24. Each of the single axis solar tracker assemblies 20 includes its own drive mechanism 26 for rotating the respective torque tube 22 and solar panels 24. As such, the solar panels 24 of each single axis solar tracker assembly 20 are rotatable independently of the solar panels 24 of the other single axis solar tracker assemblies 20 in the solar field.

[0037] Each of the single axis solar tracker assemblies 20 also includes a plurality of pillars or pylons 28 which are spaced from one another in the north-south direction and

extend in a vertical direction to respective upper attachment ends. The upper attachment end of one of the pillars 28 supports the drive mechanism 26 for controllably rotating the respective torque tube 22 and the solar panels 24, and the remaining pylons are secondary pylons 28 with bearings 30 fixed with their respective upper attachment ends to support the torque tube 22 and enable the rotation of the torque tube 22 and solar panels 24. Lower ends of the pylons 28 are attached with a base (such as, for example, the ground, a concrete slab or a roof of a building). The bearings 30 are preferably spherical bearings for allowing rotation of the torque tubes 22 and for allowing for tolerances between the bearings 30 in the axial direction.

[0038] In each single axis solar tracker assembly 20, the solar panels 24 are interconnected with the respective torque tube 22 by a plurality of rails 32 which are spaced from one another in the axial direction and support opposite edges of the solar panels 24. For assembly purposes, in the exemplary embodiment, the torque tube 22 includes a plurality of individual tubes which are co-axially joined together at splice connections. The splice connections could take any suitable form for joining the tubes together into a single torque tube 22 which extends the length of the single axis solar tracker assembly 20 and is rotatable in response to the application of a torque thereon.

[0039] The pylons 28, rails 32, torque tubes 30 and rails 32 may be made of any suitable material or combination of materials (e.g., steel, alloy steel, aluminum, aluminum alloy, etc.) and may be shaped through any suitable manufacturing process (e.g., roll forming, stamping, machining, etc.).

[0040] As shown in Figure 2, in each of the single axis solar tracker assemblies 20, the solar panels 24 are divided into two parts which are spaced from one another by a gap at an approximate axial midpoint of the single axis solar tracker assembly 20. As shown in Figure 3, the drive mechanism 26 is located at the upper attachment end of the pylon 28 in

the gap. As shown in Figure 4, the drive mechanism 26 of the exemplary embodiment includes a motor 34 and a slew drive adapter 36. The slew drive adapter 36 includes an inner ring 38 which surrounds and is fixedly attached with the torque tube 22 (shown in Figure 3) and includes an environmentally sealed housing 40. Within the housing 40, the slew drive adapter 36 includes a worm gear with a worm 42 that is connected with an output of the motor 34 and includes a gear wheel 44 that is connected with the inner ring 38. During operation, activation of the motor 34 rotates the worm 42, which drives rotation of the inner ring 38, the torque tube 22 (shown in Figure 3) and the solar panels 24 (also shown in Figure 3) about the axis. Reversing the direction of the motor 34 reverses the rotation of the solar panels 24.

[0041] The slew drive adapter 36 is preferably provided with a 60:1 gear ratio between the worm 42 and the gear wheel 44 and with a 70 degree range of articulation. This configuration has been found to require little to no maintenance for the life of the single axis solar tracker assembly 20 and also to be extremely compact and cost effective. Additionally, when the motor 34 is de-activated, the slew drive adapter 36 automatically acts as a brake to prevent forces (such as wind loads) applied to the solar panels 24 from rotating the solar panels 24 and the torque tube 22 without the need for a supplemental braking system.

[0042] The exemplary motor 34 is a brushless direct current motor, is activated/deactivated by a controller 46, and is configured to rotate the solar panels 24 by up to forty-five degrees (45 degrees) in either rotational direction from a horizontal orientation with the solar panels 24 facing directly vertically into the sky. The controller 46 may be a computer or any suitable device or devices capable of automatically activating and deactivating the drive mechanisms 26 of the single axis solar tracker assemblies 20.

[0043] Since each single axis solar tracker assembly 20 has its own motor 34 and drive mechanism 26, the single axis solar tracker assemblies 20 of the solar field shown in

Figure 1 are independently and separately controllable. That is, the solar panels 24 of one single axis solar tracker assembly 20 can be rotated independently of the solar panels 24 of the other single axis solar tracker assemblies 20. As compared to solar panel assemblies that are all linked together via a single drive mechanism, the solar field of the exemplary embodiment allows for a range of stowing strategies or configurations to be employed during high wind conditions and allows for varying row and vertical spacing between adjacent single axis solar tracker assemblies 20. Additionally, since there is no driveshaft extending between the single axis solar tracker assemblies 20, vehicles may drive between adjacent single axis solar tracker assemblies 20 for cleaning and maintenance. Further, if the drive mechanism 26 of one of the single axis solar tracker assemblies 20 malfunctions, the lost power output from the solar field is limited only to that malfunctioning single axis solar tracker assembly 20, whereas if the drive mechanism of a solar field with only a single drive mechanism malfunctions, the potential energy losses are significantly greater.

[0044] In operation, the controller 46 (which may be programmed to simultaneously control multiple or all of the drive mechanisms 26) is configured to monitor wind conditions and is in communication with the drive mechanisms 26 to adjust the orientations of the solar panels 24 of the single axis solar tracker assemblies 20 depending on current wind conditions. The solar field could include its own wind speed sensor (not shown) or may rely on an external source (such as a weather reporting service) for wind speed data.

[0045] In the exemplary embodiment, the controller 46 is configured (or programmed) to operate the drive mechanisms 26 to rotate the solar panels 22 about the respective axes to follow the sun from east to west across the sky during the day in response to the wind speed being below a first predetermined threshold wind speed, which is preferably approximately thirty-five miles per hour (35 mph). The controller 46 is also configured to operate the drive mechanisms 26 (by de-activating the motors 24) to hold the

solar panels 24 stationary in response to the wind speed being between the first predetermined threshold wind speed and a second predetermined threshold wind speed, which is preferably approximately fifty miles per hour (50 mph). The controller 46 is also configured to rotate the solar panels 24 about the axes into stowing orientations wherein the solar panels 24 are angled relative to a horizontal plane in a range of ten to thirty degrees (10-30°) in response to the wind speed exceeding the second predetermined threshold wind speed.

[0046] As shown in Figure 5b, orienting the solar panels 24 in the range of 10-30° relative to the horizontal plane during high wind conditions offers reduced aero elastic instability and slew moment without excessively increasing the moment on the pylon. Such aero elastic instability results from a two-sided vortex that introduces an oscillating effect on the single axis solar tracker assembly 20 and is maximized when the solar panels 24 are in the horizontal orientations. As such, rotating the solar panels 24 into the stowing orientations protects the pylons 28 and the slew drive adapter 36 from excessive forces, thereby improving the durability and operating lives of the single axis solar tracker assemblies 20.

[0047] Referring now to Figure 6, one stowing configuration for the solar field is shown with the solar panels 24 of the single axis solar tracker assemblies 20 being in stowing orientations. As shown, in this stowing configuration, the single axis solar tracker assemblies 20 are divided into a first group 48 and a second group 50 that are separated from one another in the north-south direction. The solar panels 24 of the first group 48 are rotated relative to a horizontal orientation in an opposite rotational direction from the solar panels 24 of the second group 50. Specifically, with respect to the perspective of Figure 6, all of the solar panels 24 of the first group 48 are rotated relative to the horizontal orientation in a counter-clockwise direction, and all of the solar panels 24 of the second group 50 are rotated relative to the horizontal orientation in a clockwise direction. In this stowing configuration, all of the solar panels 24 are oriented at approximately the same angle relative to the horizontal plane.

[0048] In the stowing configuration of Figure 7, the single axis solar tracker assemblies 20 are also disposed in first and second groups 48, 50, and each group 48, 50 has a pair of outer solar tracker assemblies and a pair of inner solar tracker assemblies. The outer solar tracker assemblies are oriented at steeper, or greater, angles relative to the horizontal plane as compared to the inner solar tracker assemblies.

[0049] In the stowing configuration of Figure 8, the solar panels 24 of adjacent single axis solar tracker assemblies 20 are angled relative to the horizontal plane in opposite rotational directions. That is, with respect to the perspective of this Figure, in the north-south direction, the solar panels 24 of the single axis solar tracker assemblies 20 alternate between clockwise and counter-clockwise rotational directions.

[0050] Referring to the flow chart of Figure 9 in addition to the structure of Figures 1-8, another aspect of the present invention is a method of operating a solar field with a plurality of single axis solar tracker assemblies 20. The method includes the step 100 of determining a wind speed. The method proceeds with the step 102 of comparing the wind speed to a first predetermined threshold wind speed (preferably, approximately 35 mph) and to a second predetermined threshold wind speed (preferably, approximately 50 mph). The method continues with the step 104 of rotating the solar panels 24 of the single axis solar tracker assemblies 20 about the respective axes to follow the sun in response to the determined wind speed being below the first predetermined threshold wind speed. The method proceeds with the step 106 of locking the solar panels 24 with the drive mechanisms 26 in response to the determined wind speed being between the first and second predetermined threshold wind speeds. The method continues with the step 108 of rotating all of the solar panels 24 of the single axis solar tracker assemblies 20 into stowing orientations with the solar panels 24 being angled in a range of 10 to 30 degrees relative to a horizontal plane.

[0051] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims.

CLAIMS

What is claimed is:

Claim 1. A solar field, comprising:

a plurality of single axis solar tracker assemblies spaced apart from one another;

each of said single axis solar tracker assemblies including a plurality of solar panels that are operably supported by a torque tube and including a drive mechanism that is operably connected with said torque tube for rotating said torque tube and said plurality of solar panels about an axis;

a controller configured to receive a wind speed and in communication with said drive mechanisms of said single axis solar tracker assemblies, and said controller being configured to operate said drive mechanisms to rotate said solar panels about said axes to follow the sun in response to the wind speed being below a first predetermined threshold wind speed and to operate said drive mechanisms to rotate said solar panels about said axes into stowing orientations wherein said solar panels are angled relative to a horizontal plane in a range of 10 to 30 degrees in response to the wind speed being above a second predetermined threshold wind speed.

Claim 2. The solar field as set forth in claim 1 and further including a wind speed sensor for measuring the wind speed and in communication with said controller.

Claim 3. The solar field as set forth in claim 1 wherein said drive mechanisms include slew drive adapters.

Claim 4. The solar field as set forth in claim 3 wherein said plurality of single axis solar tracker assemblies are divided into first and second groups that are separated from one another in a first direction and wherein in said stowing orientations, all of said solar panels of said single axis solar solar tracker assemblies in said first group are angled relative to said horizontal plane in a first rotational direction and all of said solar panels of said single axis solar tracker assemblies in said second group are angled relative to said horizontal direction in a second rotational direction that is opposite of said first rotational direction.

Claim 5. The solar field as set forth in claim 4 wherein each of said first and second groups has an outer solar tracker assembly that is furthest from the other of said first and second groups and an inner solar tracker assembly that is nearest the other of said first and second groups and wherein in said stowing orientations, said outer solar tracker assemblies are angled at a greater magnitude relative to the horizontal plane than said inner solar tracker assemblies.

Claim 6. The solar field as set forth in claim 3 wherein, when in said stowing orientations, said solar panels of adjacent single axis solar tracker assemblies are angled relative to the horizontal plane in opposite rotational directions.

Claim 7. The solar field as set forth in claim 1 wherein said second predetermined threshold wind speed is greater than said first predetermined threshold wind speed.

Claim 8. The solar field as set forth in claim 7 wherein the controller is further configured to operate said drive mechanisms to hold said solar panels stationary in response to the wind speed being between said first and second predetermined threshold wind speeds.

Claim 9. The solar field as set forth in claim 8 wherein said first predetermined threshold wind speed is approximately 35 mph and wherein said second predetermined threshold wind speed is approximately 50 mph.

Claim 10. A solar assembly, comprising:

- a plurality of pillars spaced from one another and extending in a vertical direction to upper attachment ends;
- a torque tube supported by said upper attachment ends of said plurality of pillars and being rotatable about an axis;
- a plurality of solar panels supported by said torque tube and being rotatable about said axis with said torque tube;
- a drive mechanism including a slew drive adapter operably connected with said torque tube for rotating said torque tube and said plurality of solar panels about said axis; and
- a controller configured to receive a wind speed and in communication with said drive mechanism, and said controller being configured to operate said drive mechanism to rotate said solar panels about said axis to follow the sun in response to the wind speed being below a first predetermined threshold wind speed and to operate said drive mechanism to rotate said solar panels about said axis into stowing orientations wherein said solar panels are angled relative to a horizontal plane in a range of 10 to 30 degrees in response to the wind speed being above a second predetermined threshold wind speed.

Claim 11. The solar assembly as set forth in claim 10 further including a wind speed sensor for measuring the wind speed and in communication with said controller.

Claim 12. The solar assembly as set forth in claim 10 wherein said second predetermined threshold wind speed is greater than said first predetermined threshold wind speed.

Claim 13. The solar assembly as set forth in claim 12 wherein said controller is further configured to operate said drive mechanism to hold said solar panels stationary in response to the wind speeds being between said first and second predetermined threshold wind speeds.

Claim 14. The solar assembly as set forth in claim 13 wherein said first predetermined threshold wind speed is approximately 35 mph and wherein said second predetermined threshold wind speed is approximately 50 mph.

Claim 15. A method of operating a solar field including a plurality of single axis solar tracker assemblies that are spaced from one another and that each has a plurality of solar panels that are rotatable about an axis independently of the solar panels of the other solar tracker assemblies, comprising the steps of:

determining a wind speed;

comparing the wind speed to a first predetermined threshold wind speed and to a second predetermined threshold wind speed;

in response to the determined wind speed being below the first predetermined threshold wind speed, rotating the solar panels of the solar tracker assemblies about the axes to follow the sun; and

in response to the determined wind speed being greater than the second predetermined threshold wind speed, rotating the solar panels of all of the plurality of solar trackers into stowing orientations with all of the solar panels being angled in a range of 10 to 30 degrees relative to a horizontal plane.

Claim 16. The method as set forth in claim 15 wherein the second predetermined threshold wind speed is greater than the first predetermined threshold wind speed.

Claim 17. The method as set forth in claim 16 further including the step of in response to the determined wind speed being between the first and second predetermined threshold wind speeds, locking the solar panels against rotation about the axes.

Claim 18. The method as set forth in claim 15 wherein the plurality of solar tracker assemblies are divided into first and second groups that are separated from one another in the first direction and wherein in the stowing orientations, all of the solar panels of the solar tracker assemblies in the first group are angled relative to the horizontal plane in a first rotational direction and all of the solar panels of the solar tracker assemblies in the second group are angled relative to the horizontal plane in a second rotational direction that is opposite of the first direction.

Claim 19. The method as set forth in claim 18 wherein each of the first and second groups has an outer solar tracker assembly furthest from the other of the first and

second groups and an inner solar tracker assembly nearest the other group and, in the stowing orientations, the outer solar tracker assemblies are angled at a greater angle relative to the horizontal plane than the inner solar tracker assemblies.

Claim 20. The method as set forth in claim 13 wherein the solar panels of adjacent solar tracker assemblies are angled relative to the horizontal plane in opposite rotational directions when in the stowing orientations.

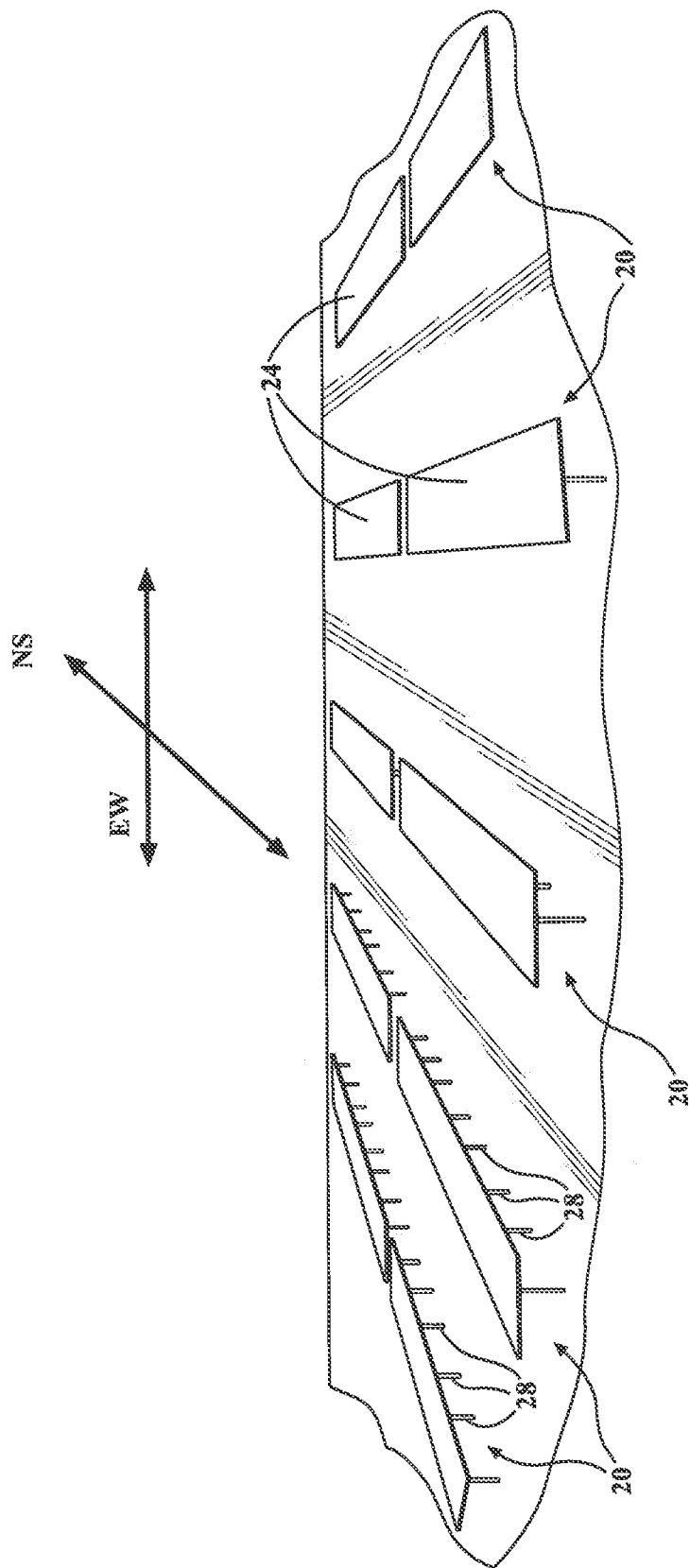


FIG. 1

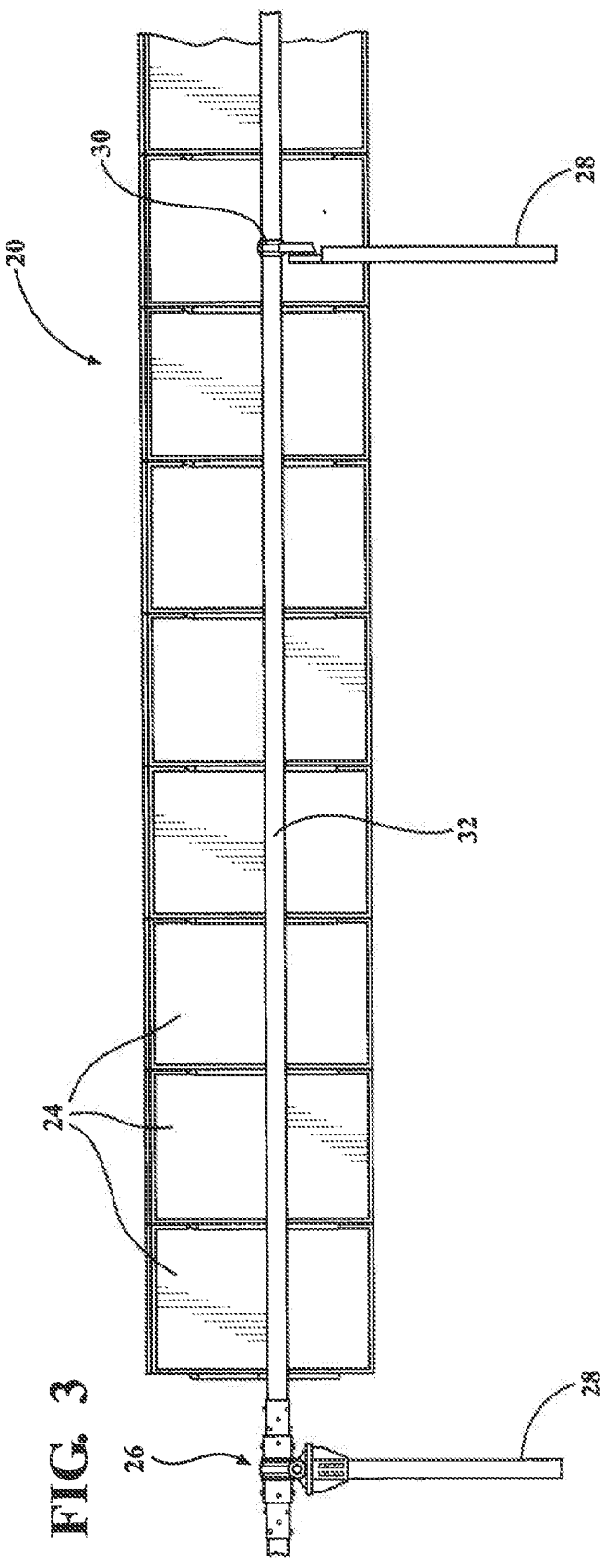
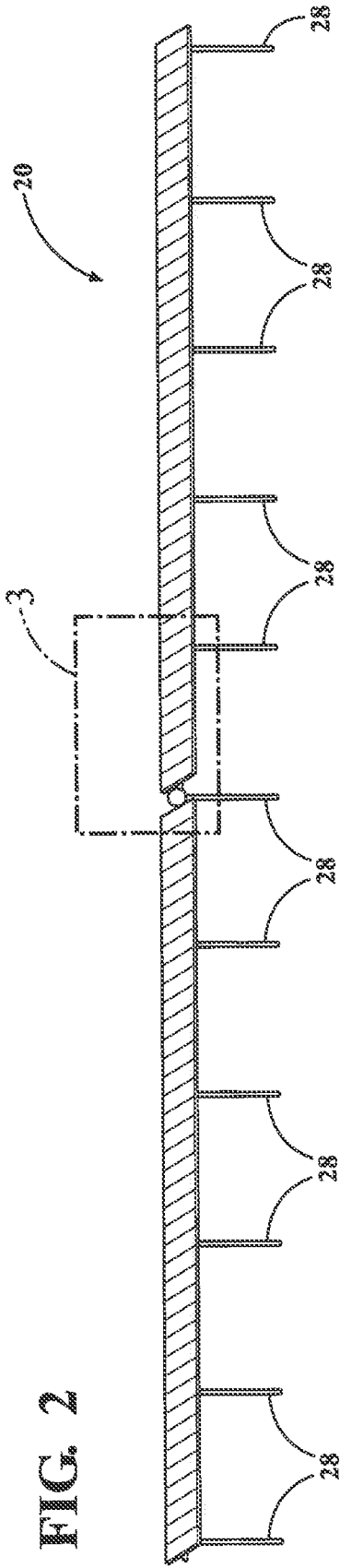
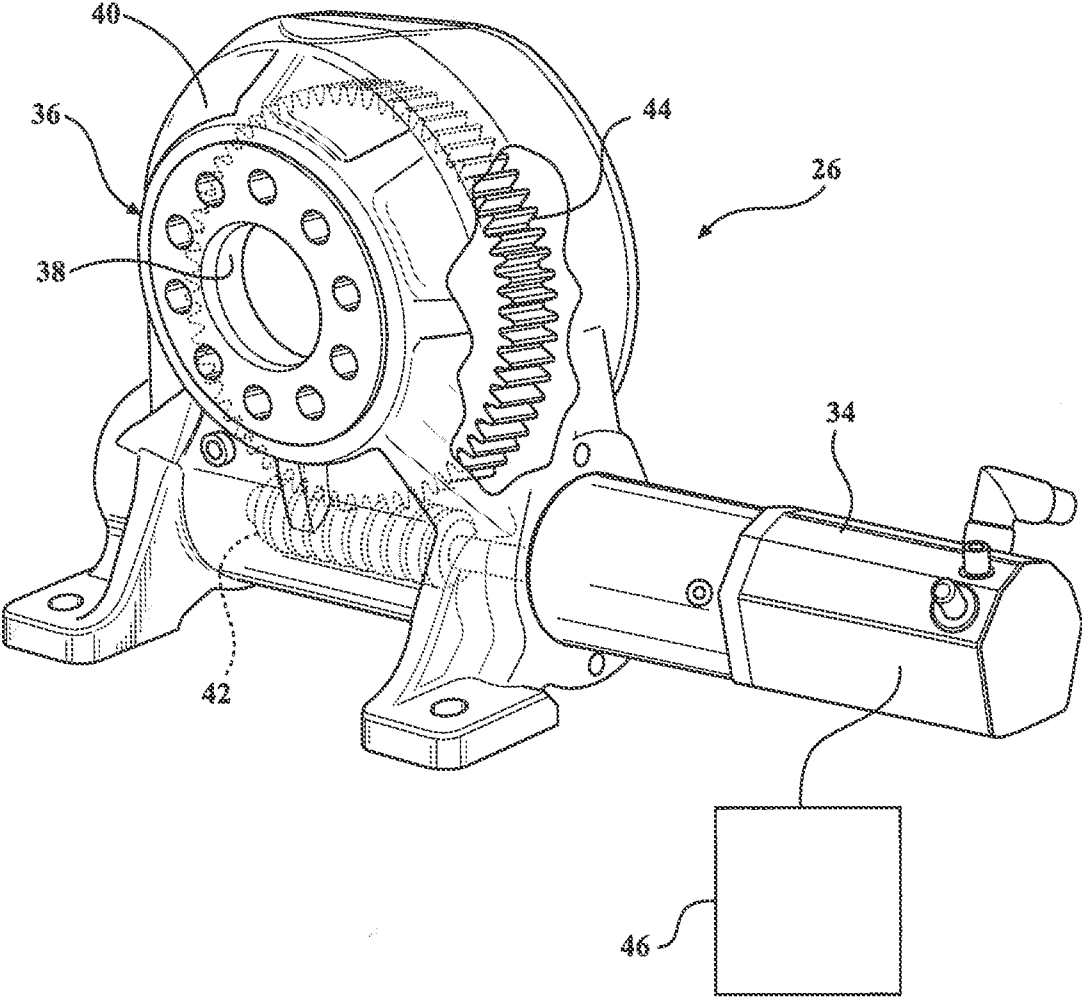
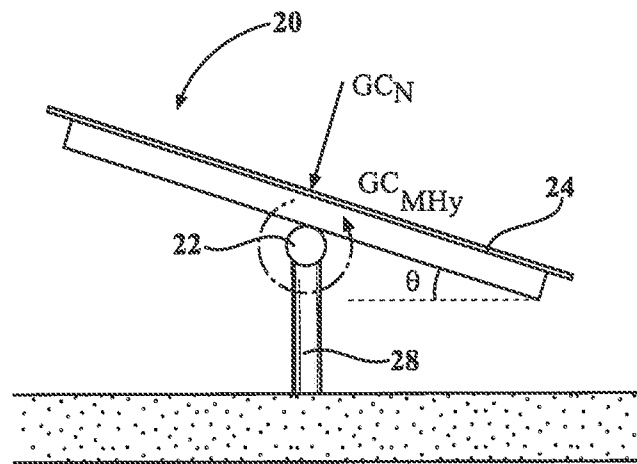


FIG. 4

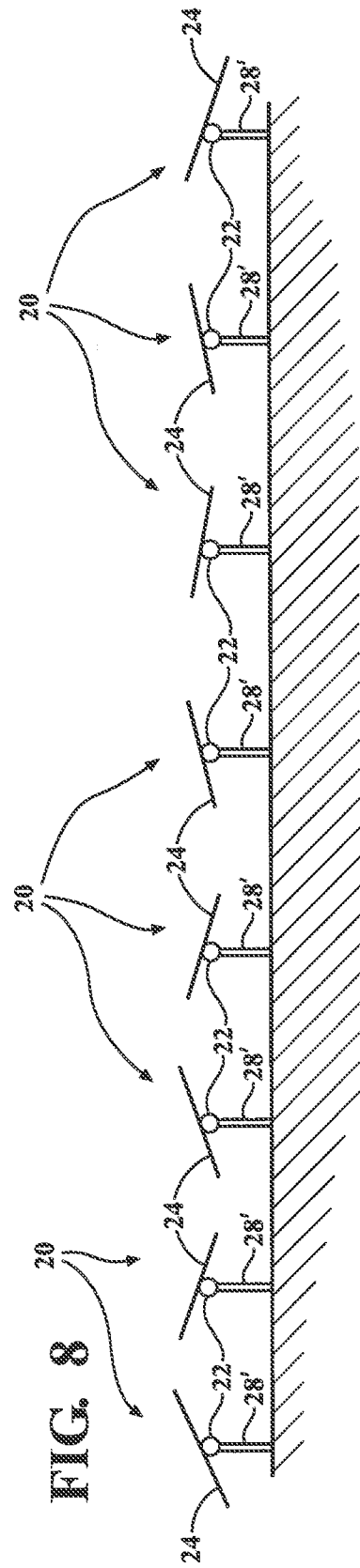
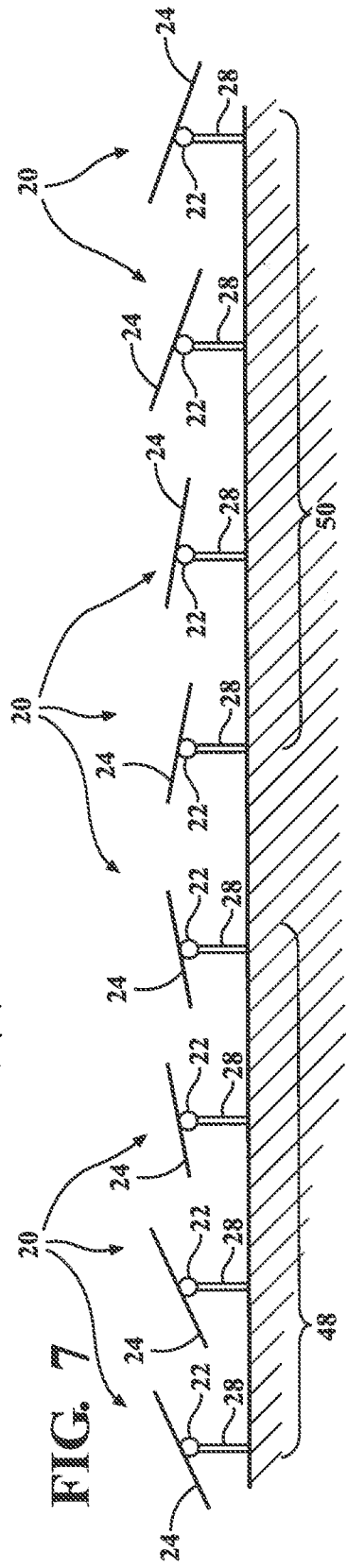
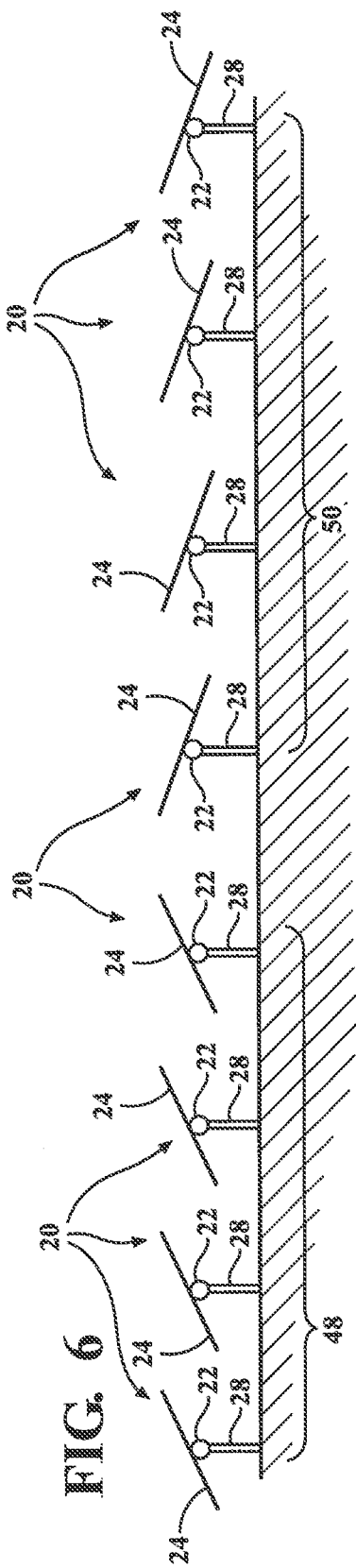


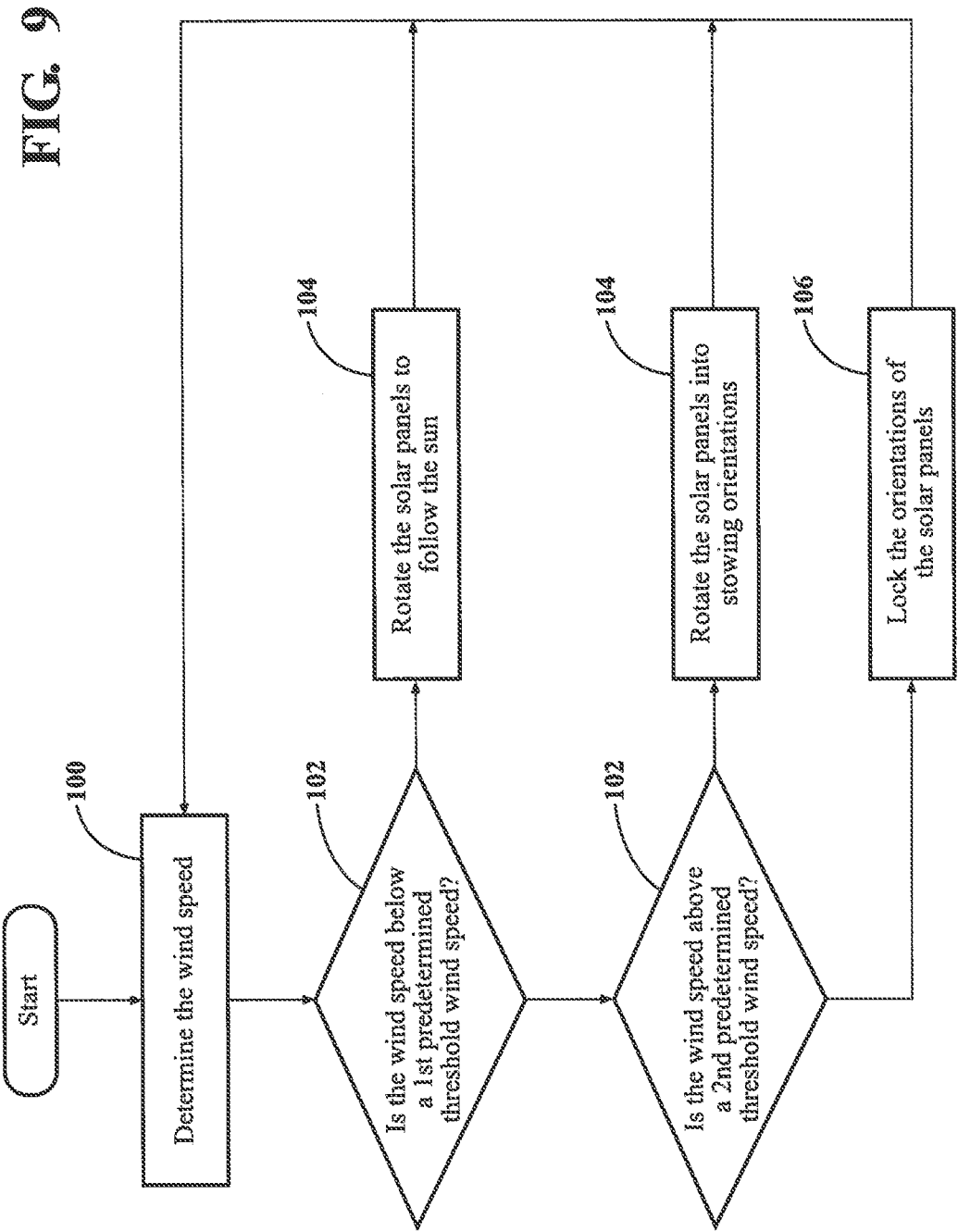
**FIG. 5a**

At 105 mph

Angle Deg θ	Max Slew Moment GC_{MHy} kN-m	Max Pile Moment GC_N kN-m	Aero Elastic Instability
0	43.9	4.65	High
5	41.4	4.65	
10	39.0	9.26	
15	34.1	13.80	
20	29.2	18.23	
25	26.7	22.59	
30	26.7	26.95	
35	26.7	31.31	
40	26.7	35.67	
45	26.6	40.03	Low

FIG. 5b





INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/41422

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F24J 2/00, F24J 2/38, F24J 2/46, F24J 2/52, F24J 2/54 (2016.01)

CPC - F24J 2/00, F24J 2/46, F24J 2/405, F24J 2/4638, F24J 2/52, F24J 2/54, F24J 2/5403, F24J 2002/0038 -see extra sheet-
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

CPC: F24J2/00, F24J2/46, F24J2/4607, F24J2/4638, F24J2/52, F24J2/54, F24J2/5403, F24J2002/0038, F24J2002/5434, F24J2002/5448, F24J2002/5462, F24J2002/5468, H02S20/00, H02S20/10, H02S20/30, H02S20/32, Y02E10/00, Y02E10/40,

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

IPC (8): F24J2/00, F24J2/38, F24J2/46, F24J2/52, F24J2/54, H01L31/00, H01L31/02, H01L31/04, H01L31/042, H02N6/00 (2016.01)
CPC: Y02E10/47, Y02E10/50, F24J2/*, F24J2002/*

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Patbase, Google (Web, Images, Patents, Scholar)

Wind, solar, filed, array, assemblies, speed, threshold, rotate, direction, spin, urge, axis, single, torque, tube, drive, motor, mechanism, control, angle, degrees, first, second, oriented, response, measure, stow, protect, high, intense, damage, react.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y — A	US 2013/0048048 A1 (Flanery et al.) 28 February 2013 (28.02.2013) entire document, especially Title, Abstract, figs. 1a-3, para [0018]-[0024].	1-4, 6-14 5
Y — A	US 2013/0133641 A1 (Shvets) 30 May 2013 (30.05.2013) entire document, especially Title, Abstract, figs. 1-5, para [0047]-[0066].	1-4, 5-14 5
A	US 2003/0062037 A1 (Hayden et al.) 3 April 2003 (03.04.2003) entire document.	1-14
A	US 2013/0019921 A1 (Au) 24 January 2013 (24.01.2013) entire document.	1-14
A	US 2008/0308091 A1 (Corio) 18 December 2008 (18.12.2008) entire document.	1-14

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 September 2016

Date of mailing of the international search report

02 DEC 2016

Name and mailing address of the ISA/US

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/41422

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-14, drawn to a solar field.

Group II: Claims 15-20, drawn to a method of operating a solar field.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

--See Extra Sheet--

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-14

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/41422

Continuation of A: CLASSIFICATION OF SUBJECT MATTER

CPC: F24J 2002/5434, F24J 2002/5448

-*-Continuation of Box III - Observations where unity of invention is lacking*-*

Special Technical Features

The invention of Group I includes the special technical features of solar panels having a specific actuation structure operably supported by a torque tube and including a drive mechanism that is operably connected with said torque tube for rotating said torque tube and said plurality of panels about an axis and a controller configured to receive wind speed and communicate with said drive mechanism.

The invention of Group II includes the special technical features of a method of operating a solar field including a plurality of single axis solar tracker assemblies that are spaced from one another and that each has a plurality of solar panels that are rotatable about an axis independently of the solar panels of the other solar tracker assemblies comprising the steps of:

determining a wind speed,
comparing the wind speed to a first predetermined threshold wind speed and to a second predetermined threshold wind speed,
in response to the determined wind speed being below the first predetermined threshold wind speed rotating the solar panels of the solar tracker assemblies about the axes to follow the sun,
and in response to the determined wind speed being greater than the second predetermined threshold wind speed, rotating the solar panels of all of the plurality of solar trackers into stowing orientations with an of the solar panels being angled in a range of 10 to 30 degrees relative to an horizontal plane.

Common Technical Features

The inventions of Groups I and II share the technical features of a solar field, comprising
a plurality of single axis solar tracker assemblies spaced apart from one another,
each of said single axis solar tracker assemblies configured to rotate said solar panels about said axes to follow the sun in response to the wind speed being below a first predetermined threshold wind speed and to operate said drive mechanisms to rotate said solar panels about said axes into stowing orientations wherein said solar panels are angled relative to a horizontal plane in a range of 10 to 30 degrees in response to the wind speed being above a second predetermined threshold wind which does not provide any contribution over the prior art as it is anticipated by US 2013/0133641 A1 to Shvets.

Shvets teaches a system of sun tracking assemblies (Title; Abstract; fig.1) wherein a plurality of sun tracking assemblies are heliostats or PV cells (see para [0066]), wherein a controller (91; fig.5; para[0047]) provides control over a comprehensive set of manners, orientations and sub assemblies (para [0050]-[0052]) of said sun trackers, to provide multiple methods and systems for achieving optimal heat generation or energy conversion during sun tracking, while providing extensive measures to ensure wind conditions do not cause damage to any of the components in the system, in a particular safety mode (para[0050]-[0051]) during strong/intense winds sun-tracking assemblies orient to a stow configuration to reduce the potential for wind induced damage, further said assemblies include a wind- protection mode (buffering mode) when threshold value for wind speed is exceeded (para[0035]) said sun tracking assemblies are oriented to include an angle offset from the horizon or horizontal and may include staggered orientation angles wherein a reorientation angle is in the range of 10-80 degrees and may result in an inclination angle of between 20-70 degrees based on detected or predicted increase in wind speed (para[0037]-[0038]).

As the common features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Therefore, Groups I-II lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.