US 20140053825A1

(19) United States

(12) Patent Application Publication

Zhou

(10) Pub. No.: US 2014/0053825 A1

(43) Pub. Date: Feb. 27, 2014

(54) **GANGED SINGLE AXIS SOLAR TRACKER AND ITS DRIVE SYSTEM**

(71) Applicant: **Suzhou Jinshan Solar Science and Technologies Co., Ltd.**, (US)

(72) Inventor: **Yin Zhou**, Changsu (CN)

(73) Assignee: **Suzhou Jinshan Solar Science and Technologies Co., Ltd.**, Changshu City (CN)

(21) Appl. No.: **13/804,797**

(22) Filed: **Mar. 14, 2013**

Related U.S. Application Data

(63) Continuation-in-part of application No. PCT/CN2012/080586, filed on Aug. 25, 2012.

(60) Provisional application No. 61/699,371, filed on Sep. 11, 2012.

(30) **Foreign Application Priority Data**

Aug. 25, 2012 (CN) 2012 1030 6130.9

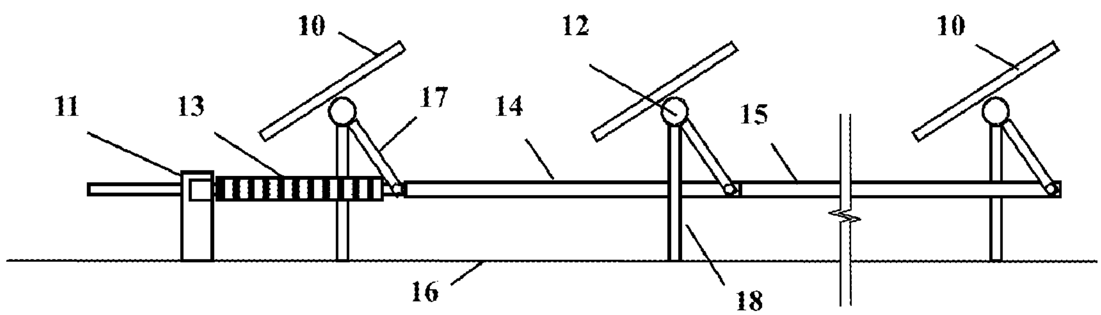
Publication Classification

(51) **Int. Cl.**
F24J 2/54 (2006.01)

(52) **U.S. Cl.**
CPC ***F24J 2/541*** (2013.01)
USPC **126/606**

(57) **ABSTRACT**

The present invention involves a ganged single axis solar tracker and its drive system having at least two rows of solar trackers and a drive mechanism. Each tracker row shares one common rotation axis and the at least two tracker rows are placed in parallel. At least one torque arm is rigidly and perpendicularly connected to the each tracker rotation axis. The drive mechanism has at least one rotary actuator, such as a slew drive, whose rotation axis is parallel to the tracker rotation axes. At least one drive torque arm is rigidly and perpendicularly connected to the drive rotation axis. The drive torque arm and the tracker torque arms are hinge connected with a series of rigid beams. The linkage beams are perpendicular to the tracker and drive rotation axes. The rotary drive rotates and creates a rotation movement. The drive torque arm follows the rotation movement of the drive, which consequently converts a linear push-pull movement in the linkage beams. The linkage beams push and pull the tracker torque arms, rocking the at least two rows of solar trackers to rotate about their axes and to follow the sun's movement.



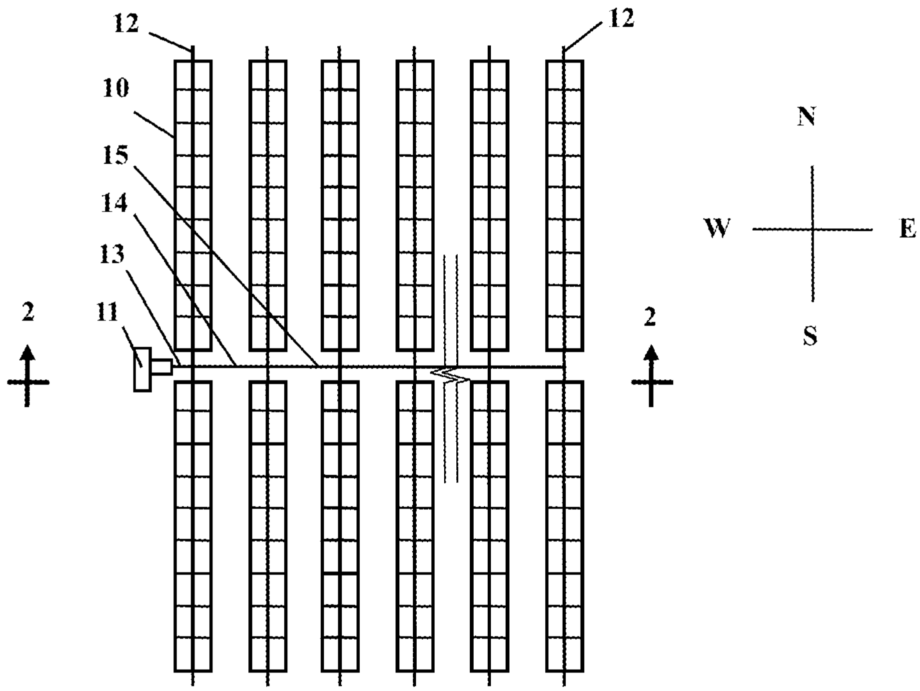


FIG. 1

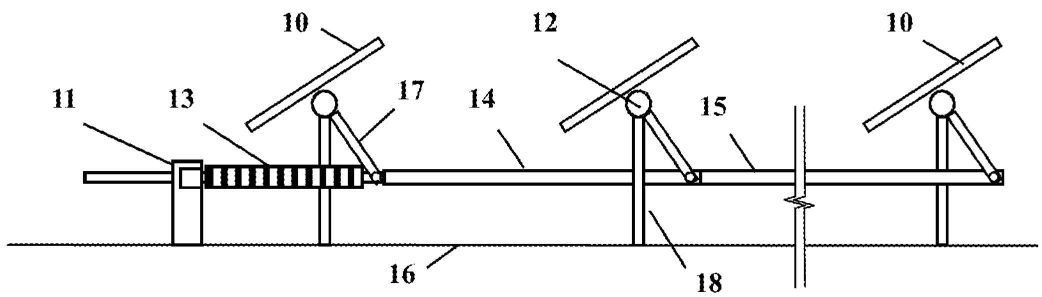


FIG. 2

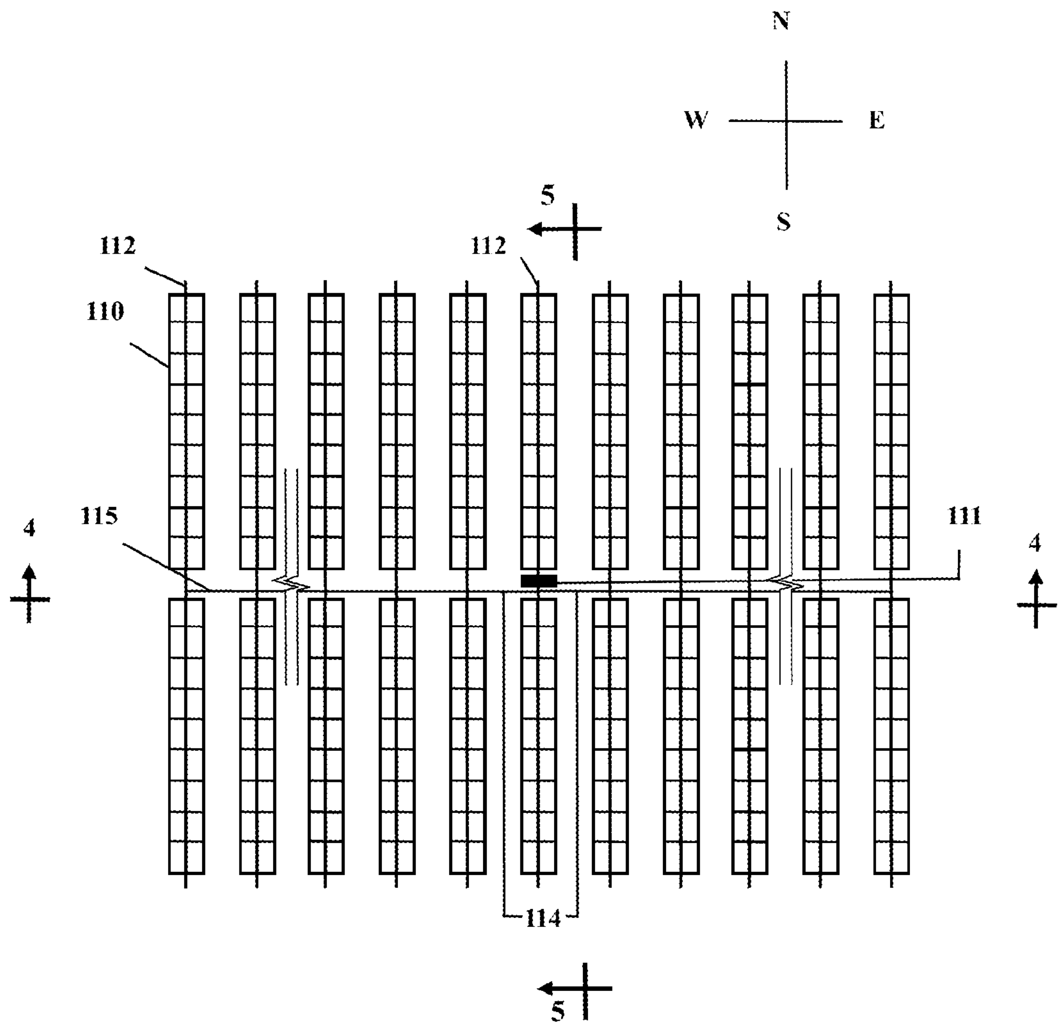


FIG. 3

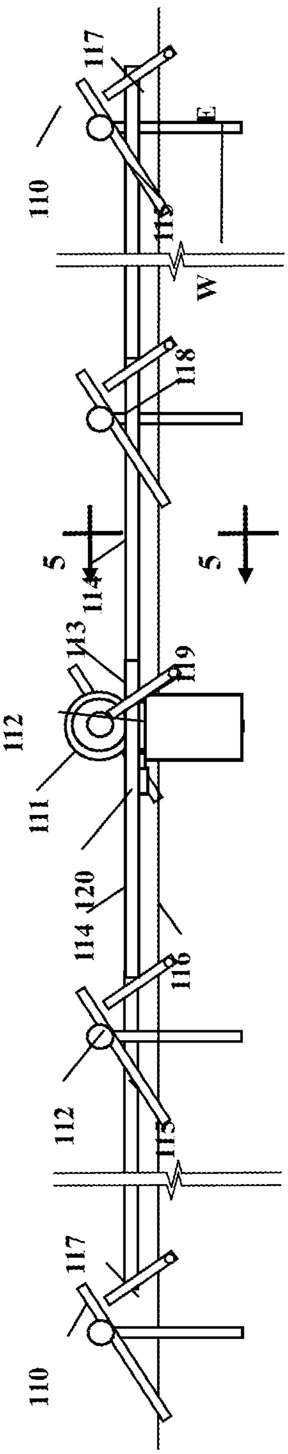


FIG. 4

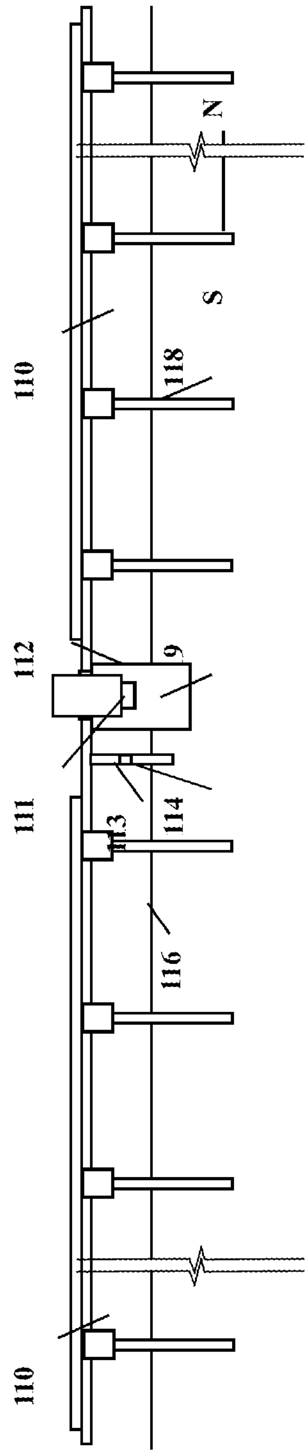


FIG. 5

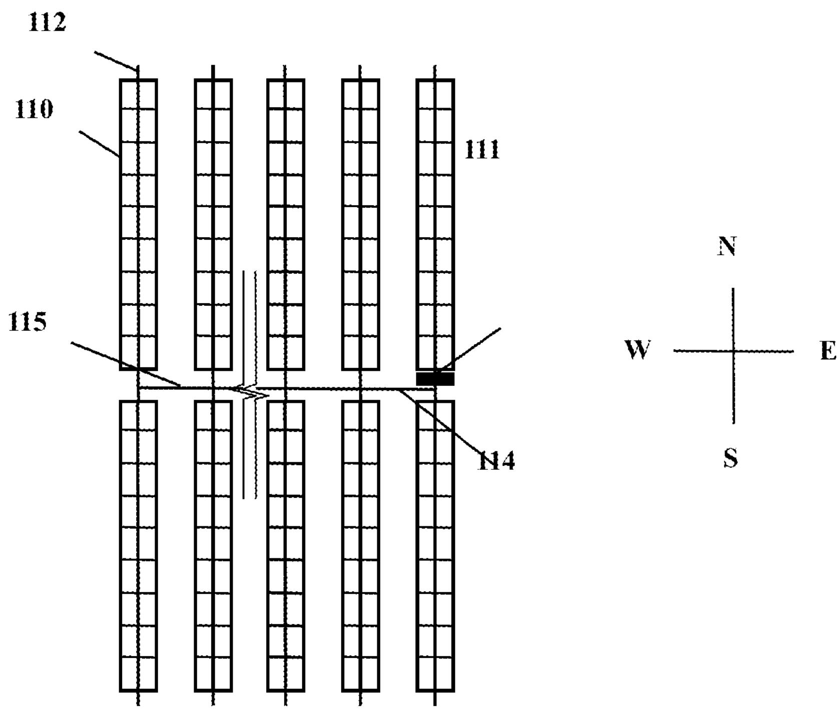


FIG. 6

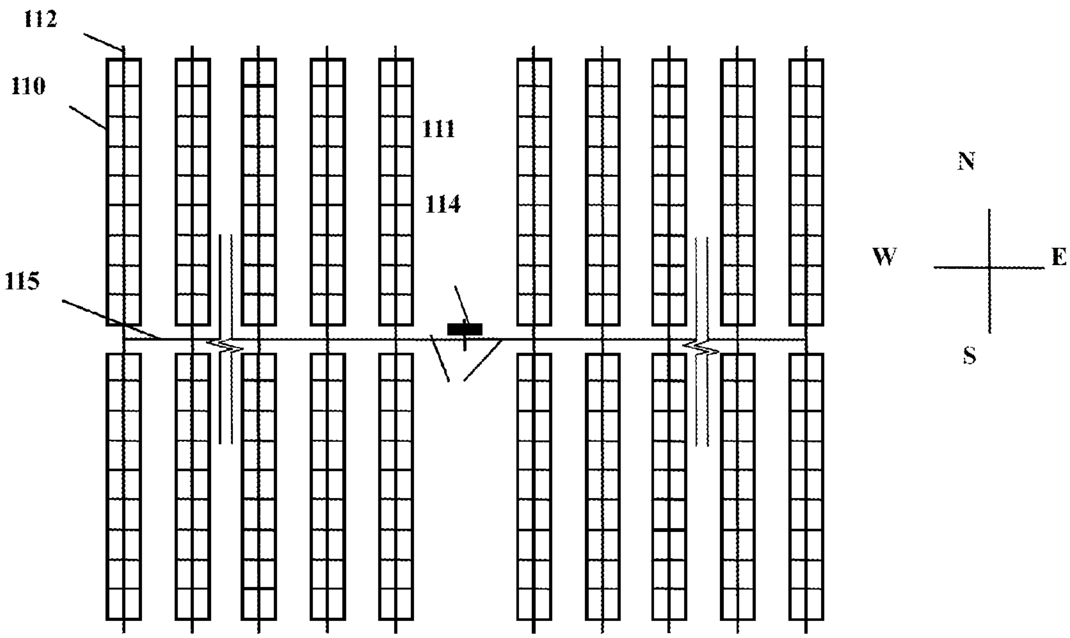


FIG. 7

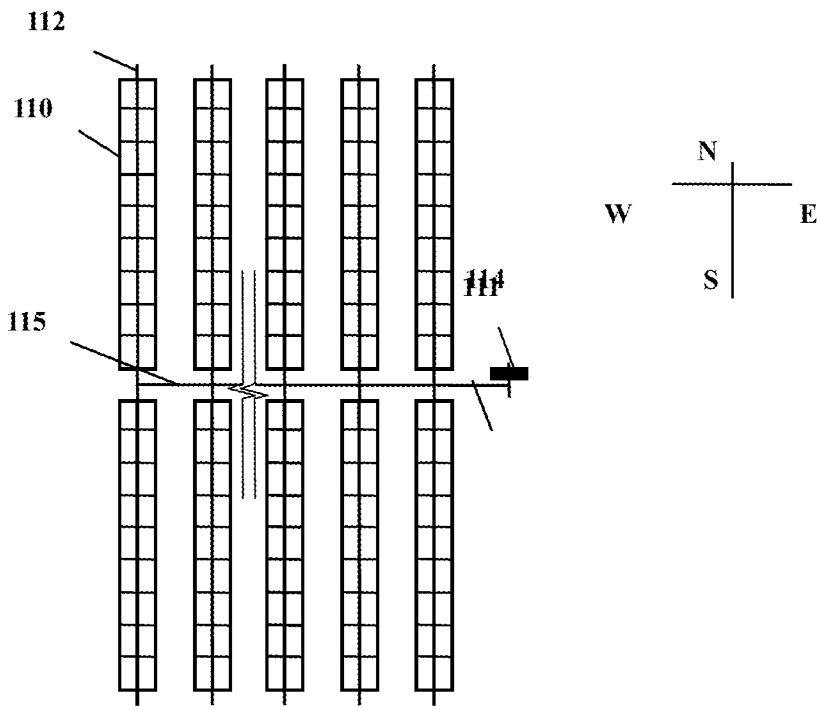


FIG. 8

GANGED SINGLE AXIS SOLAR TRACKER AND ITS DRIVE SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to solar energy production and more particularly to an apparatus for driving a number of rows of solar receivers to follow the motion of the sun relative to the earth.

[0003] 2. Description of the Related Art

[0004] Solar energy has gradually become an important alternative power resource to help achieve the goal of sustainable development. Solar power has a few unique advantages such as it is clean, abundant, and it produces when the consumption is high. The biggest challenge the solar energy is currently facing is its relatively high cost. Solar tracking systems can improve incident angles of solar receivers such as solar thermal or photovoltaic modules (PV). These tracking devices have been successfully used to improve power production efficiency, and thus to reduce solar power generation costs.

[0005] The prior art single axis trackers typically have one motor/drive per tracker row, thus limiting the total area of solar receivers driven by each motor/drive. Solar tracker array using this technology will have high costs due to generally increased material usage, field construction work, as well as maintenance requirements. In order to reduce costs associated with tracking, U.S. Pat. No. 6,058,930, to Shingleton, described a ganged single axis solar tracker system. In this system, multiple solar trackers are linked together with a linear motion linkage and operated by a single linear actuator, such as a hydraulic or screw jack, attached to a separate foundation located away from the solar tracker array. The advantage of such a system is clear since the costs of motor and drive system have been shared by multiple tracker rows, thus the tracking costs per PV module have been substantially reduced. The system has also limitations. Firstly, the first linkage member close to the drive has to withstand wind loads on the entire tracker array, thus it becomes less economy when the tracker array increases in size. Secondly, the linear actuator produces large up and down forces onto the foundations and tracker beams near the drive, increasing costs for these affected members. Thirdly, the drive has to be located away from the tracker array, thus requiring extra land.

SUMMARY OF THE INVENTION

[0006] In accordance with an aspect of the present invention, a ganged single axis solar tracker array has at least two rows of solar trackers and a drive mechanism. The said solar trackers have rotation axes; solar receivers are mounted onto the tracker rotation axes. Solar trackers in one row are rotatorily mounted onto at least one foundation and share one common rotation axis. The at least two tracker rows are placed in parallel. At least one torque arm is rigidly and perpendicularly connected to the each tracker rotation axis. The rotation center of the torque arm is coincident with the tracker rotation axis onto which the torque arm is affixed. The driver mechanism has at least one rotary actuator, such as a slew drive, whose rotation axis is parallel to the tracker rotation axes. At least one drive torque arm is rigidly and perpendicularly connected to the drive rotation axis. The rotation center of the drive torque arm is coincident with the drive rotation axis. The drive torque arm and the tracker torque arms are hinge linked with a series of rigid beams. The linkage beams are perpendicular to the tracker and drive rotation axes. The rotary drive rotates to create a rotation movement. The drive torque arm follows the rotation movement of the drive, which consequently converts a linear push-pull movement in the linkage beams. The linkage beams push and pull the tracker torque arms, rocking the tracker rows to rotate about their axes and to follow the sun's movement.

[0007] The rotation centers of the two torque arms on any two adjacent tracker rows, and the two connecting joints between the two torque arms and the linkage beam, form the four corner points of a quadrilateral. Similarly, the rotation center of the drive torque arm, the rotation center of an adjacent torque arm, and the two connecting joints between the two torque arms and the linkage beam, form the four corner points of a quadrilateral.

[0008] In one embodiment, a ganged single axis solar tracker system has at least two rows of solar trackers and a drive mechanism. The solar trackers have rotation axes; solar receivers are mounted onto the tracker rotation axes. Solar trackers in one row are rotationally mounted on at least one foundation and share one common rotation axis. At least two tracker rows are placed in parallel. At least one torque arm is rigidly and perpendicularly connected to the each tracker rotation axis. The rotation center of the torque arm is coincident with the tracker rotation axis onto which the torque arm is affixed.

[0009] In one embodiment, the drive mechanism has at least one rotary actuator whose rotation axis is parallel to the tracker rotation axes. The rotary actuator may be a slew drive, a worm gear, a planetary gear, or a slew ring. At least one drive torque arm is rigidly and perpendicularly connected to the drive rotation axis. The rotation center of the drive torque arm is coincident with the drive rotation axis. The drive torque arm and the tracker torque arms are hinge connected with a series of rigid beams. The linkage beams are perpendicular to the tracker and drive rotation axes.

[0010] In one embodiment, the rotation axis of the rotary actuator may be coincident with the rotation axis of one tracker row within the tracker array, and may also be parallel to and away from the rotation axis of any tracker row of the tracker array. The rotation axis of the rotary actuator may further be located within or outside of the tracker array, and may be flat, tilted to the ground, or vertical.

[0011] In one embodiment, the tracker rotation beam may be of round or square cross section, or truss. The ganged single axis solar tracker drive mechanism links and drives at least two rows of solar trackers. The solar trackers have rotation axes; solar receivers are mounted onto the tracker rotation axes. Solar trackers in one row are rotatorily mounted onto at least one foundation and share one common rotation axis. At least two tracker rows are placed in parallel. The single axis solar tracker drive mechanism comprises of multiple torque arms which are perpendicularly and rigidly connected to the said each tracker rotation axis. The rotation center of each torque arm is the tracker rotation axis onto which the said each torque arm is affixed.

[0012] One embodiment of the single axis solar tracker drive mechanism further comprises of at least one rotary actuator or drive. The rotary drive has one rotation axis which is parallel to the said tracker rotation axes. At least one drive torque arm is rigidly and perpendicularly connected to the said drive rotation axis. The rotation center of the drive torque arm is coincident with the drive rotation axis. The said at least one drive torque arm and the tracker torque arms are hinge connected with a series of rigid beams. The linkage beams are perpendicular to the tracker and drive rotation axes.

[0013] In an exemplary embodiment, the rotary drive shares the rotation axis of a tracker row, which can be a center row, a side row, or any other row within the tracker array.

[0014] In another embodiment, the rotary drive has its rotation axis apart from any tracker rows. The drive axis can be located near the center of, in between any two adjacent tracker rows within, or on one side and away from, the tracker array.

[0015] The rotary drive includes but is not limited to slew drive, worm gear, planetary gear, or slew ring. The tracker and drive rotation axes are horizontal, tilted, or vertical to the earth. The tracker rotation beams vary by shapes, including but are not limited to round, square, and so forth. Apparently to those skilled in the art, the rotation beams may be composed of truss, tubular or any composite of these members. The solar receivers include but are not limited to flat panels, flat or parabolic reflectors/mirrors for the use of solar photovoltaic, thermal or concentrator.

[0016] In another aspect of the present invention, a drive mechanism is employed to drive at least two rows of solar trackers. Trackers have rotation beams onto which solar panels are affixed. Trackers in one row share one common rotation axis which are rotationally mounted on at least one foundation and the at least two tracker rows are placed in parallel. The drive mechanism comprises of: at least one torque arm which is rigidly and perpendicularly connected to the each tracker rotation axis, and the rotation center of the torque arm is coincident with the tracker rotation axis onto which the torque arm is affixed; at least one rotary actuator, such as a slew drive, whose rotation axis is parallel to the tracker rotation axes; at least one drive torque arm which is rigidly and perpendicularly connected to the drive rotation axis, and the rotation center of the drive torque arm is coincident with the drive rotation axis. The at least one drive torque arm and the tracker torque arms are hinge connected with a series of rigid beams. The said linkage beams are perpendicular to the tracker and drive rotation axes.

[0017] The ganged single axis tracker and its drive mechanism has the following advantages: firstly, solar trackers can be conveniently placed in a mirror layout about the rotary drive axis, and the maximum force endured by the linkage member equals only to the forces from half of the entire solar array. In another words, the linkage member with the same size in the present invention can drive twice as many solar panels as per the prior art. Secondly, the drive system in embodiments of the present invention distributes wind forces in more appropriate manners since it produces no additional uplift and down forces on nearby foundations and beams, nor large compression force in the drive unit which could lead to buckling failure in the screw jack as in the prior art. Thirdly, the drive can share the tracker axis or be located within the tracker array such that no additional land is required.

[0018] The above and many other objects, features, and advantages of this invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the claimed invention. The objects and advantages of the claimed invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The above mentioned and other features and objects of this invention, and the manner of attaining them, will become more apparent and the invention itself will be better understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

[0020] FIG. **1** illustrates a plan view of the prior art which employs a linear actuator to drive multiple single axis tracker rows.

[0021] FIG. **2** illustrates an east-west side view of the prior art which employs a linear actuator to drive multiple single axis tracker rows (or Section **2-2** in FIG. **1**).

[0022] FIG. **3** illustrates a plan view of an embodiment of the current invention, in which the drive axis coincident with one tracker axis near the center of the tracker array.

[0023] FIG. **4** illustrates an east-west side view of an embodiment of the current invention, in which the drive axis coincident with one tracker axis near the center of the tracker array (or Section **4-4** in FIG. **3**).

[0024] FIG. **5** illustrates a north-south side view of an embodiment of the current invention, in which the drive axis coincident with one tracker axis near the center of the tracker array (or Section **5-5** in FIG. **3**).

[0025] FIG. **6** illustrates a plan view of the second embodiment of the current invention, in which the drive axis coincident with one tracker axis located at the end of the tracker array.

[0026] FIG. **7** illustrates a plan view of the third embodiment of the current invention, in which the drive axis is in-between and away from two adjacent tracker rotation axes within the tracker array.

[0027] FIG. **8** illustrates a plan view of the fourth embodiment of the current invention, in which the drive axis is on one side of and away from the tracker array.

[0028] Corresponding reference characters indicate corresponding parts throughout the several views. Although the drawings represent embodiments of the present invention, the drawings are not necessarily to scale and certain features may be exaggerated in order to better illustrate and explain the present invention. The exemplification set out herein illustrates an embodiment of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF EMBODIMENTS OF THE PRESENT INVENTION

[0029] The embodiments disclosed below are not intended to be exhaustive or limit the invention to the precise form disclosed in the following detailed description. While the invention is subject to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and will herein be described in detail. The invention should be understood to not be limited to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention. Rather, the embodiment is chosen and described so that others skilled in the art may utilize its teachings.

[0030] With reference to the Drawings, and initially to FIGS. **1** and **2**, a ganged single axis solar tracker array according to the prior art is shown. Multiple torque tubes in a row share a north-south axis **12**, and a number of solar receivers **10**

are attached onto the tubes. At least two rows of trackers are placed in parallel and apart from each other to form a tracker array from east to west. Each tracker row **12** is rotationally mounted on at least one foundation **18**, which is supported on the ground **16**. A torque arm **17** is rigidly and perpendicularly connected to each of the tracker rotation axis **12**. The drive system according to the prior art comprises of a linear actuator **13** such as a hydraulic or screw jack which is supported on a foundation **11** above the ground **16**, and a series of rigid linkage beams **14** and **15** which connect the torque arms **17**. A linear movement such as retraction or extension in the linear actuator **13** produces a push or pull movement in the linkage beams **14** and **15**; the linkage beams push or pull the torque arms **17**, which in turn create a rotation movement of each solar tracker row about their axis **12**. The solar tracker and its drive system according to the prior art has the following characteristics: (1) the drive is a linear actuator; (2) the linear actuator is located on one side of and away from the solar tracker array (in this example, it is shown on the west; it can be on the east side as well); the linear actuator and its foundation use additional land on top of the land occupied by the solar array; (3) the first linkage beam **14** has to take the wind forces transferred from all solar receivers except the first row from the drive. When the number of rows of the tracker array increases, the load that the first linkage beam **14** has to bear is high; (4) the linear actuator **13** and linkage beams **14** and **15** are subject to compression forces, which could lead to buckling damages within these parts; thus the size of the tracker array is substantially limited; and (5) the rotation center of the linear actuator, the rotation center of the first torque arm **17**, and the connection point of the first linkage beam **14** and the first torque arm **17**, form the three corner points of a triangle.

[0031] An embodiment of this invention is shown in FIGS. **3** to **5**, which show a solar tracker array and its drive system, in its plan view (FIG. **3**), east-west view (FIG. **4**) and north-south view (FIG. **5**), respectively. The solar tracker array comprises of multiple rows of solar trackers placed in parallel and aligned in north-south orientation, and its drive mechanism which rocks the solar trackers to follow the sun's east-west movement. Trackers in one row share the same rotation axis **112** onto which solar receivers **110** are mounted. Each tracker row is rotationally mounted on at least one foundation **118**, which is supported on the ground **116**. In each tracker row, a torque arm **117** is rigidly and perpendicularly connected to its rotation axis **112**. The rotation center of the torque arm **117** is coincident with the tracker rotation axis **112** onto which the torque arm is affixed. The drive system of the tracker array comprises of a rotary actuator or drive such as a slew drive **111**. The drive is mounted on a drive foundation **119** which is affixed to the ground **116**. In general, a motor (as well as a controller) **120** is mechanically connected with the drive. The rotary drive has a rotation axis or drive axis and a drive torque arm **113** is rigidly and perpendicularly connected to the drive axis. The rotation center of the drive torque arm **113** is coincident with the drive rotation axis. The rotary drive is placed near the center of the solar tracker array, and it rotation axis is coincident with one tracker rotation axis. The drive torque arm is hinge connected with other torque arms **117** thru a series of rigid beams **114** and **115**. The rigid linkage beams **114** and **115** are perpendicular to the tracker axes. The two connection points between any two adjacent torque arms **113** or **117** and the linkage beam **114** or **115**, and the rotation centers of the two torque arms **113** or **117**, form the four corner points of a quadrilateral. A rotary movement within the drive **111** rocks the center tracker row and the drive torque arm **113** rotates about the rotation axis **112**. The rotary movement of the drive torque arm converts to a linear push-pull movement within the linkage beams **114** and **115**. The linkage beams push or pull the torque arms **117** to rock the each tracker row to rotate about the each tracker rotation axis **112**. Generally, the rigid linkage members are articulated to one another and to the torque arms of the respective rows of solar trackers, thus allowing the solar trackers to be employed on uneven terrain.

[0032] The solar tracker array and its drive system according to this invention as shown in FIGS. **3** to **5** has the following characteristics: (1) the drive is rotary actuator, such as a slew drive; (2) the drive axis shares one tracker rotation axis near the center of the tracker array; no additional land is needed for the drive and its foundation; (3) the largest force the first linkage beam **114** has to take is equal to the forces on the east or west half of the tracker array instead of that from the entire tracker array; (4) the drive and the drive torque arm do not bear large compression forces; and (5) The rotation center of the drive or the drive torque arm, the two connection points of the first linkage member **114** between the drive torque arm and the first tracker torque arm, and the rotation center of the first tracker torque arm, form the four corner points of a quadrilateral.

[0033] In the first example, the rotary is a slew drive. In this and other applications, the rotary actuator or drive can also be slewing ring, planetary or worm gear. The optimal drive can be determined based on economy and site conditions. The use of various rotary drive types should be covered by the present invention.

[0034] In the first embodiment, the drive axis shares the rotation axis of the center tracker. Apparently, the drive axis can conveniently be coincident with any other tracker rotation axis within the tracker array. In accordance with such an aspect of the present invention, the second embodiment of this invention is shown in FIG. **6**. The difference between the second and first embodiment lies in that the drive axis in the second embodiment shares the end tracker rotation axis.

[0035] The third embodiment of this invention is shown in FIG. **7**. In this example, the drive axis is located near the center of the tracker array while it is apart from any tracker rotation axis.

[0036] In the fourth embodiment of this invention as shown in FIG. **8**, the drive axis is located on one side of and apart from the tracker array.

[0037] In any particular applications of the present invention, solar receivers can all have the same or various initial tracker angles; the tracker rotation beam can be of round or square cross section, a truss or any other composite structure.

[0038] In all embodiments as shown the tracker axes are flat. It is not difficult to persons skilled in the art that the tracker axes can be aligned tilted to the ground or vertical.

[0039] The term "ground" as used in reference to the foundation is not limited to earth or soils, but can be a rooftop or any other supporting structures.

[0040] While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.

What is claimed is:

1. A ganged single axis solar tracker system comprising at least two rows of solar trackers and a drive mechanism, said solar trackers have rotation axes and solar receivers; said solar receivers being mounted onto the tracker rotation axes, said solar trackers in one row being rotationally mounted on at least one foundation and share one common rotation axis, at least two tracker rows being placed in parallel with at least one torque arm being rigidly and perpendicularly connected to the each tracker rotation axis, a rotation center of the torque arm being coincident with the tracker rotation axis onto which the torque arm is affixed; said drive mechanism having at least one rotary actuator whose rotation axis is parallel to the tracker rotation axes, wherein said at least one drive torque arm is rigidly and perpendicularly connected to the drive rotation axis, the rotation center of the torque arm being coincident with the drive rotation axis, wherein the drive torque arm and the tracker torque arms are hinge connected with a series of rigid beams having linkage beams that are perpendicular to the tracker and drive rotation axes.

2. A ganged single axis solar tracker system according to claim **1** wherein said rotary actuator is a slew drive, a worm gear, a planetary gear, or a slew ring.

3. A ganged single axis solar tracker system according to claim **1** wherein said rotation axis of the rotary actuator is coincident with the rotation axis of one tracker row within the tracker array.

4. A ganged single axis solar tracker system according to claim **1** wherein said rotation axis of the rotary actuator is parallel to and away from the rotation axis of any tracker row of the tracker array.

5. A ganged single axis solar tracker system according to claim **4** wherein said rotation axis of the rotary actuator is located within or outside of the tracker array.

6. A ganged single axis solar tracker system according to claim **1** wherein said rotation axes of the rotary actuator and trackers are flat, tilted to the ground, or vertical.

7. A ganged single axis solar tracker system according to claim **1** wherein said tracker rotation beam is of round or square cross section, or truss.

8. A ganged single axis solar tracker drive mechanism for linking and driving at least two rows of solar trackers, wherein the solar trackers have rotation axes and solar receivers that are mounted onto the tracker rotation axes, and wherein solar trackers in one row are rotatorily mounted onto at least one foundation and share one common rotation axis with at least two tracker rows being placed in parallel, the single axis solar tracker drive mechanism comprising: a plurality of torque arms which are perpendicularly and rigidly connected to each of the tracker rotation axes, a rotation center of each torque arm being coincident with the tracker rotation axis onto which each torque arm is affixed, said single axis solar tracker drive mechanism further comprising of at least one rotary actuator drive having one rotation axis which is parallel to the tracker rotation axes, and at least one drive torque arm which is rigidly and perpendicularly connected to the drive rotation axis, wherein a rotation center of the drive torque arm is coincident with the drive rotation axis, the at least one drive torque arm and the tracker torque arms being hinge connected with a series of rigid linkage beams, the linkage beams being perpendicular to the tracker and arranged to drive rotation axes.

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