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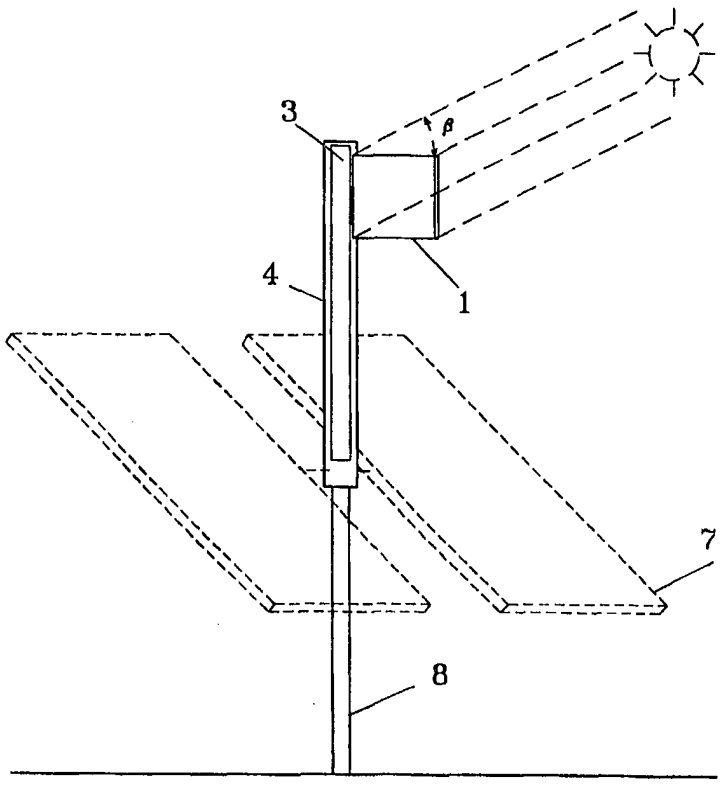
(54) Title: AN APPARATUS FOR ORIENTATION OF SOLAR RADIATION COLLECTORS

(57) Abstract

An apparatus comprising at least one solar cell (1) fixed to a rotary axle (4) of the apparatus in such a way that a plane of the cell (1) is declined by 0.1–45 angular degrees from a plane perpendicular to collectors (7) of solar energy and parallel with a rotary axle (4) of the apparatus to the east, the solar cell (1) being directly connected to an electromotor (3) that is jointed with the rotary axle (4) of the apparatus, for orientation of the rotary axle (4) of the apparatus as long as a power of the cell (1) is higher than the power necessary for orientation of the rotary axle (4) of the apparatus. When comprising two antiparallel connected solar cells (1, 2), these cells (1, 2) are approximately planar, having approximately the same parameters, being approximately parallel to each other, and can be placed in a common case (5). The solar cells (1, 2) can be on a common substrate. The electromotor (3) can be preferably placed in the rotary axle (4) of the apparatus and provided with a self–locking transmission (6).



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Description

An Apparatus for Orientation of Solar Radiation Collectors

Technical Field

The invention relates to the field of apparatuses for orientation of solar radiation collectors.

Prior Art

Existing active solar trackers are usually based on electrooptical solar sensors as descibed for instance in U.S. Patents 3.493.765, 4.223.214, 4.328.417 and 5.317.145. Such trackers can work with a high accuracy. These trackers are complex and, therefore, expensive and unreliable. Electrooptical solar trackers are usually composed of at least one pair of antiparallel connected photoresistors or photovoltaic solar cells which are electricaly balanced by an equal intensity of illumination of both elements so that there is either no or negligible control signal on a driving motor. A differential control signal, occurred by a differential illumination of electrooptical sensors, is used to drive a motor and to orientation of an apparatus in such direction where illumination of electrooptical sensors is equal and a balance is restored.

There are other active solar trackers based on clockworks and/or combining both principles as described in U.S. patent 4.031.385. Such trackers can work with high accuracy but they are complex and, therefore, expensive and little reliable.

Existing passive solar trackers are based on thermal expansion of matter and/or on shape memory alloys. They are usually composed of couple of actuators working against each other which are balanced by equal illumunation. An unbalance of forces caused by a differential illumination of actuators is used for orientation of the apparatus in such a direction where there is an equal illumination of actuators and a balance of forces is restored, as described e.g. in U.S. patents 2.967.249 and

4.027.651, GB patent 1.566.797, CZ patent 279.801 and DE 33 03 000 A1. Passive solar trackers compared to active trackers are less complex and less expensive but they work with low efficiency and they do not work at low temperatures at all.

Both active and passive solar trackers use for a diffferential illumination of sensors and actuators shadowing means, mirrors or lenses and/or arrangement of sensors or actuators to each other and/or combination of the above mentioned means as it is described e.g. in patents U.S. 4.082.947 and SU1474397 and DE 43 06 656 A1.

For instance, two axis solar tracking is reached by sensing solar cells placed symmetricaly on concurrent faces of a pyramid or truncated pyramid while an axis of symmetry is defined by the vertex of the pyramid and by the sun. A single axis solar tracking is reached by sensing solar cells placed symmetrically on concurrent faces of a triangular prism or truncated triangular prism while a plane of symmetry is defined by the intersection of concurrent planes and by the sun.

Concurrent symmetrical arrangement of antiparallel connected solar cells is advantageous for accurate tracking of the sun as it compensates isotropic and circumsolar diffuse parts of solar radiation that decrease an accuracy of tracking.
A direct radiation only is used for tracking of the sun in this case.

A disadvantage of this arrangement is reduction of power of solar cells as a diffuse circumsolar radiation represents a substantial part of the solar raduiation energy.

A total output power of concurrently arranged antiparallel connected solar cells is further decreased as only a differential power can be used for tracking. A low efficiency of concurrently arranged antiparallel connected solar cells substantially increases a price of the apparatus as a price of solar cells represents a substantial part of price of the apparatus.

A further disadvantage of concurrently arranged antiparallel connected solar cells is late backtracking of solar collectors in the morning as the apparatus that

finished tracking in the preceding day afternoon has no solar cell oriented to the east. It is the reason why backtracking starts at late morning when the sun is high enough above horizon. Use of auxiliary solar cells for backtracking increases price and complexity of the apparatus. Use of curved solar cells increases the price too. Bigger cells have to be used for the same output power due to the fact that only a part of cells is illuminated. Besides, the partial illumination could damage solar cells.

Disclosure of Invention

The present invention avoids mentioned disadvantages of the prior art concerning apparatuses for orientation of solar radiation collectors using driving/sensing solar cells.

The invention is characterized in that an apparatus for orientation of solar radiation collectors comprises at least one solar cell for conversion of solar energy to electrical energy that is fixed to a rotary axle of the apparatus in such a way that a plane of the cell is declined by 0.1-45 angular degrees from a plane perpendicular to collectors of solar energy and parallel with the rotary axle of the apparatus to the east and the solar cell is connected to an electromotor which is jointed with the rotary axle of the apparatus, for orientation of the rotary axle of the apparatus as long as the power of the cell is higher than the power necessary for orientation of the rotary axle of the apparatus.

As the sun moves from the east to the west, angle β of incidence of solar radiation on sensing/driving cells is increasing up to the moment when the power of the driving D.C.motor, connected to these cells, is high enough to move solar collectors. Then the angle β of incidence starts to decrease up to the moment when the power of the D.C. motor is lower than that one necessary to move solar collectors. The apparatus uses a negative feedback.

The angle 0.1-45 degrees by which the solar cell is declined from a plane perpendicular to collectors of solar energy and parallel with the rotary axle of the apparatus to the

east is adjusted for the output power of the solar cell to be close to a threshold necessary for orientation of the apparatus and simultaneously for a maximum of solar energy to be collected by solar collectors. A value of the angle depends especially on parameters of the apparatus and on a local climate and it is usually about 20^0.

The power of the sensing cells is balanced by a friction in the structure of the apparatus according to the invention and by an aerodynamic drag. It is the reason why the apparatus can work with one solar cell only. The apparatus remains afternoon oriented westvards. The next day in the morning, the apparatus has to be reoriented to the east manually. Additional antiparallel solar cells, placed in the same panel, enables backtracking of the tracker. In the apparatus according to invention one solar cell only is illuminated by direct solar radiation.

Existing trackers use at least two sensing/driving solar cells balanced to each other and their differential power is used to overcome the friction and the aerodynamic drag. Tracking the sun by existing apparatuses for orientation of solar radiation collectors, both antiparallel connected solar cells are illuminated by a direct solar radiation.

The apparatus according to the invention uses a direct solar radiation and it usually uses the whole, not only a differential, power of the solar cells connected to the electromotor. Additionally, the apparatus uses a diffuse circumsolar radiation and compensates only a low power isotropic diffuse radiation.

The function of the apparatus does not depend on an exact adjustment of antiparallel solar cells as it is designed for tracking accuracy about $\pm 10^0$. This is the reason why neither exactly planar nor exactly parallel solar cells are needed.

The arrangement according to the invention enables a production of antiparallel solar cells on common substrate and an integration of antiparallel solar cells in one "bifacial" panel. As expenses of manufacturing and encapsulation of solar cells represent a substantial part of the price of the apparatus, the new solution according to the invention enables substantial reduction of its price.

A parallel arrangement of solar cells according to the invention enables using a diffuse circumsolar part of the solar radiation that is compensated a concurrent arrangement of solar cells. The diffuse circumsolar part of the solar radiation that decreases an accuracy of tracking the sun can be used as the accuracy of tracking the sun, necessary to maximize a collectible solar energy,is decreasing by increasing a diffuse part of the solar radiation.

The accuracy necessary to maximize a colectible solar energy in the case of prevailing direct solar radiation is about $\pm 10^0$. The accuracy necessary to maximize a colectible solar energy in the case of prevailing diffuse solar radiation is about $\pm 30^0$. If there is a diffuse isotropic solar radiation only, tracking the sun is not necessary.

Using the circumsolar diffuse part of the solar radiation enables to collect maximum solar energy amout by an optimum but not a maximum accuracy of tracking the sun.

The apparatus can use photovoltaic, thermoelectric or photoelectrochemical cells and/or combined cells.

An electromotor fixation in a rotary axle simplifies an assembly of the apparatus and its design is more compact than existing design with linear electrical actuators. The electromotor can be provided with a self-locking transmission that protects the motor against damage by external forces, for instace by wind surges.

Connection of the electromotor directly to solar cells, without any electronic circuits, substantially increases reliability of the apparratus.

The new arrangement according to the invention is generally less expensive, more simple, more compact and more efficient than existing solar trackers and it enables an early morning apparatus backtracking.

The new tracker with tracking accuracy $\pm 10^0$ enables to collect by flat plates and low concentration collectors of solar radiation nearly the same amount of solar radiation as more expensive electronic trackers with tracking accuracy $\pm 0.1^0$ that are designed especially for a high concentration collectors of solar radiation.

Brief Description of Drawings

Figures schematically show examples only of the arrangement of the apparatus according to the invention. Fig.1 shows an apparatus for orientation of solar radiation collectors with a vertical rotary axle provided with one auxiliary solar panel. An apparatus for orientation of solar radiation collectors with a horizontal rotary axle provided with two auxiliary solar panels is shown in Fig.2 in an initial morning orientation, in Fig.3 in an active position after sunrise and in Fig.4 in a position before sunset. Fig.5 shows a solar tracker with a polar rotary axle and Fig.6 shows a solar tracker with a horizontal rotary axle provided with two auxiliary solar panels placed in a common case. An apparatus provided with two auxiliary solar panels with different parameters is shown in Fig.7 where dot arrows represent an isotropic diffuse solar radiation, continuous arrows represent a circumsolar diffuse radiation and dashed arrows represent a direct solar radiation. Fig.8 shows a complete wiring diagram of an electromotor and solar cells.

Examples of Invention Embodiment

Example 1

An apparatus for orientation of solar radiation collectors 7 shown in Fig.1 comprises one solar cell 1 for conversion of solar energy to electrical energy that is fixed to a rotary axle 4 of the apparatus in such a way that a plane of the cell 1 is declined by 20 angular degrees from a plane perpendicular to collectors 7 of solar energy and parallel with the rotary axle 4 of the apparatus to the east, the solar cell 1 being connected directly to an electromotor 3 that is fixed in the hollow rotary axle 4 of the apparatus.

The apparatus works as follows.

The apparatus is oriented eastwards before sunrise. An angle β of a solar radiation incidence on the sensing/driving solar cell 1 increases as the sun moves from the east to the west up to the moment when the power of the driving D.C.electromotor 3, connected to this cell 1, is high enough to move solar collectors 7. Then the incidence angle β starts to decrease up to the moment when the power of the D.C. electromotor 3 is lower than that one necessary to move solar collectors 7. The apparatus uses a negative feedback. The apparatus with one auxiliary solar cell 1 remains oriented westvards in the afternoon. The next day, the apparatus has to be reoriented to the east manually in the morning.

A range of an automatic orientation of solar radiation collectors 7 is approximately 150^0 -2β in this arrangement.

Example 2

Figures 2.,3. and 4. show a variant of an apparatus for orientation of solar radiation collectors that comprises a solar cell 1 and an auxiliary solar cell 2 which are parallel to each other and antiparallel connected , having approximatelly the same parameters. The solar cells 1, 2 are connected to the reversible D.C.electromotor 3 that is fixed in a hollow rotary axle 4 of the apparatus. The solar cells 1, 2 are fixed to the horizontal rotary axle 4 of the apparatus in such a way that the plane of the cell 1 is declined by 20 angular degrees from the plane perpendicular to collectors 7 of solar energy and parallel with the rotary axle 4 of the apparatus to the east

The apparatus works as follows.

The apparatus is oriented eastwards before sunrise. After sunrise, the solar radiation is shining under a big angle on the auxiliary solar panel 2 that is connected to the reversible D.C.electromotor 3 . The reversible D.C.electromotor 3 powered by the auxiliary solar panel 2 moves the apparatus to the sun until the angle β between the auxiliary solar cell 2 and solar radiation shining on the cell 2 is small enough that the

uotput power of the auxiliary solar cell 2 is lower than the power necessary to move the apparatus.

The apparatus is oriented eastwards. The sun moves in the angle 2β on the sky. The collectors of solar energy 7 do no follow the sun in this angle. As the sun moves further to the west, solar radiation is shining under big angle on the solar cell 1 that is connected to the reversible D.C.electromotor 3. The electromotor 3 powered by the solar panel 1 moves the apparatus to the sun until the angle β between the solar cell 1 and solar radiation shining on the cell 1 is small enough that the output power of the solar cell 1 is lower than the power necessary to move the apparatus. Fig. 3 shows that either the solar cell 1 or the solar cell 2 is always exposed to the sun.

A range of an automatic orientation of solar radiation collectors is approximately 150^0-2β in this arrangement.

Example 3

Fig.5 shows a variant of the apparatus for orientation of solar radiation collectors that comprises a solar cell 1 and an auxikiary solar cell 2 which are parallel to each other, antiparallel connected , having approximatelly the same parameters. The solar cells 1, 2 are connected to the reversible D.C.electromotor 3 that is fixed in a hollow rotary axle 4 of the apparatus. The solar cells 1, 2 are fixed to a polar rotary axle 4 of the apparatus in such a way that a plane of the cell 1 is declined by 20 angular degrees from the plane perpendicular to collectors 7 of solar energy and parallel with the rotary axle 4 of the apparatus to the east.

The apparatus works the same way as the apparatus in example 2.

Example 4

Fig.6 shows a variant of the apparatus for orientation of solar radiation collectors that comprises a solar cell 1 and an auxikiary solar cell 2 which are antiparallel connected, manufactured on a common substrate, placed in a common case and have approximatelly the same parameters. The solar cells 1, 2 are connected to the reversible D.C.electromotor 3 that is fixed in a hollow rotary axle 4 of the apparatus and is provided with a self-locking tramsmission 6. The solar cells 1, 2 are fixed to a horizontal rotary axle 4 of the apparatus in such a way that a plane of the cell 1 is declined by 20 angular degrees from the plane perpendicular to collectors 7 of solar energy and parallel with the rotary axle 4 of the apparatus to the east.

The apparatus works as follows.

The apparatus is oriented eastwards before sunrise. After sunrise, a solar radiation is shining under big angle on the auxiliary solar panel 2 that is connected to the reversible D.C.electromotor 3 . The reversible D.C.electromotor 3 powered by the auxiliary solar panel 2 moves the apparatus to the sun until the angle β between the auxiliary solar cell 2 and solar radiation shining on the cell 2 is small enough that the uotput power of the auxiliary solar cell 2 is lower than the power necessary to move the apparatus.

The apparatus is oriented eastwards. The sun moves in the angle 2β on the sky. The collectors 7 of solar energy do no follow the sun in this angle. As the sun moves further to the west, a solar radiation is shining under big angle on the solar cell 1 that is connected to the reversible D.C.electromotor 3. The electromotor 3 powered by the solar panel 1 moves the apparatus to the sun until the angle β between the solar cell 1 and solar radiation shining on the cell 1 is small enough that the uotput power of the solar cell 1 is lower than the power necessary to move the apparatus. If the external torque, caused e.g. by the wind, is higher than the torque of the D.C.electromotor 3, a self-locking tramsmission 6 locks up the rotary axle 4.

Example 5

Fig.7 shows a variant of the apparatus for orientation of solar radiation collectors that comprises a solar cell 1 and an auxikiary solar cell 2 which are parallel to each other, antiparallel connected , having approximatelly the same parameters. The solar cells 1, 2 are connected to the reversible D.C.electromotor 3 that is fixed in a hollow rotary axle 4 of the apparatus. The solar cells 1, 2 are fixed to a horizontal rotary axle 4 of the apparatus in such a way that a plane of the cell 1 is declined by 20 angular degrees from the plane perpendicular to the collectors 7 of solar energy and parallel with the rotary axle 4 of the apparatus to the east

The apparatus works the same way as the apparatus in example 2.

Preceding description of the arrangement of the apparatus for orientation of solar radiation collectors shows only some variants of the apparatus and does not represent all existing variants of the apparatus possible according to the invention.

Industrial Applicability

The apparatus for orientation of solar radiation collectors according to the invention is applicable in any equipment using solar energy for various aims, e.g. heating water, conversion to electric power etc.

(End of description)

Claims

1. An apparatus for orientation of solar radiation collectors fixed to a rotary axle of the apparatus which is rotationally jointed to the stator, including a solar cell fixed to the rotary axle of the apparatus **characterized in that** at least one solar cell (1) for conversion of solar energy to electrical energy is fixed to a rotary axle (4) of the apparatus in such a way that a plane of the cell (1) is declined by 0.1-45 angular degrees from the plane perpendicular to collectors (7) of solar energy and parallel with the rotary axle (4) of the apparatus to the east and the solar cell (1) is connected to an electromotor (3) that is jointed with the rotary axle (4) of the apparatus, for orientation of the rotary axle (4) of the apparatus as long as the power of the cell (1) is higher than the power necessary for orientation of the rotary axle (4) of the apparatus.

2. The apparatus according to the claim 1 **characterized in that** it has at least two antiparallel connected solar cells (1,2) which are approximately planar, having approximately the same parameters, being approximately parallel to each other, and an electromotor (3) that is reversible.

3. The apparatus according to the claim 2 **characterized in that** antiparallel connected solar cells (1,2) are placed in a common case.

4. The apparatus according to the claim 2 **characterized in that** antiparallel connected solar cells (1,2) are on a common substrate and placed in a common case.

5. The apparatus according to the claims 1 to 4 **characterized in that** the electromotor (3) is fixed in the rotary axle (4) of the apparatus, being provided with a self-locking transmission (6) whith its shaft fixed to the stator (8).

6. The apparatus according to the claims 1 to 5 **characterized in that** the solar cells (1,2) are photovoltaic.

7. The apparatus according to the claims 1 to 5 **characterized in that** the solar cells (1,2) are photoelectrochemical.

8. The apparatus according to the claims 1 to 5 **characterized in that** the plane of the solar cells (1,2) is declined by 0.1-45 angular degrees from the plane perpendicular to collectors (7) of solar energy and parallel with the rotary axle (4) of the apparatus to the east

9. The apparatus according to the claims 1 to 5 **characterized in that** the solar cells (1,2) are combined photovoltaic and photoelectrochemical.

10. The apparatus according to the claims 1 to 9 **characterized in that** the solar cells (1,2) are connected directly to the electromotor (3).

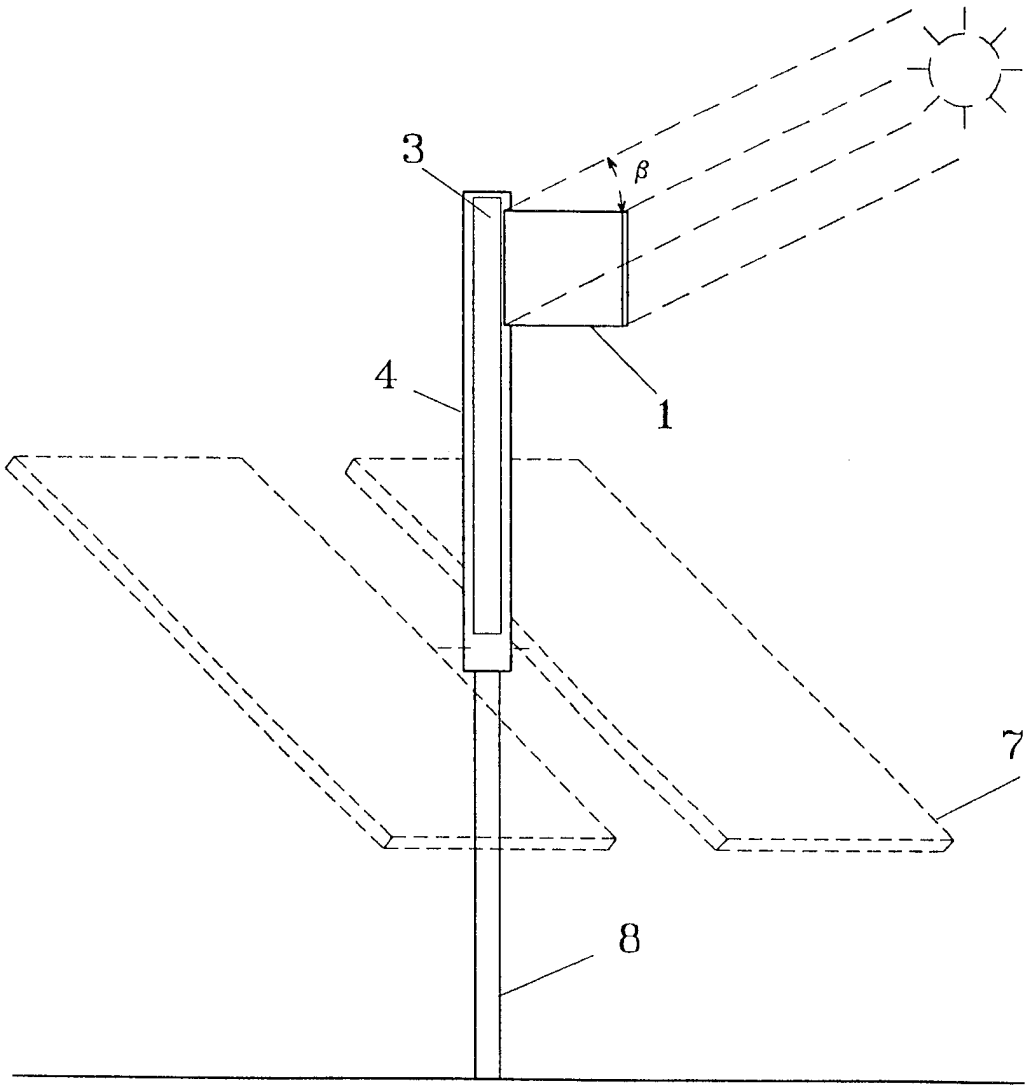

Fig. 1.

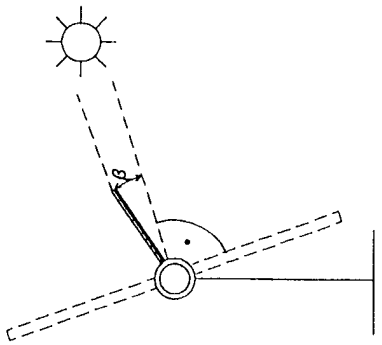

Fig. 4.

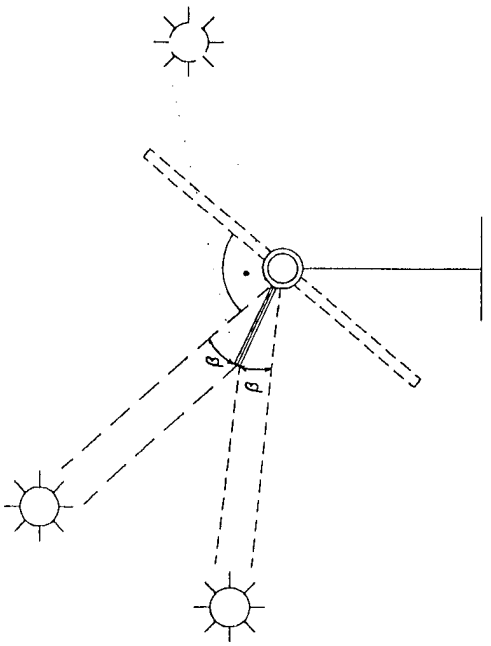

Fig. 3.

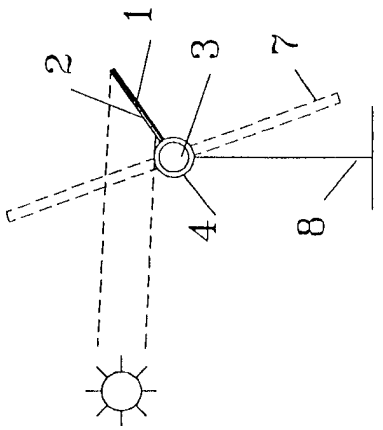

Fig. 2.

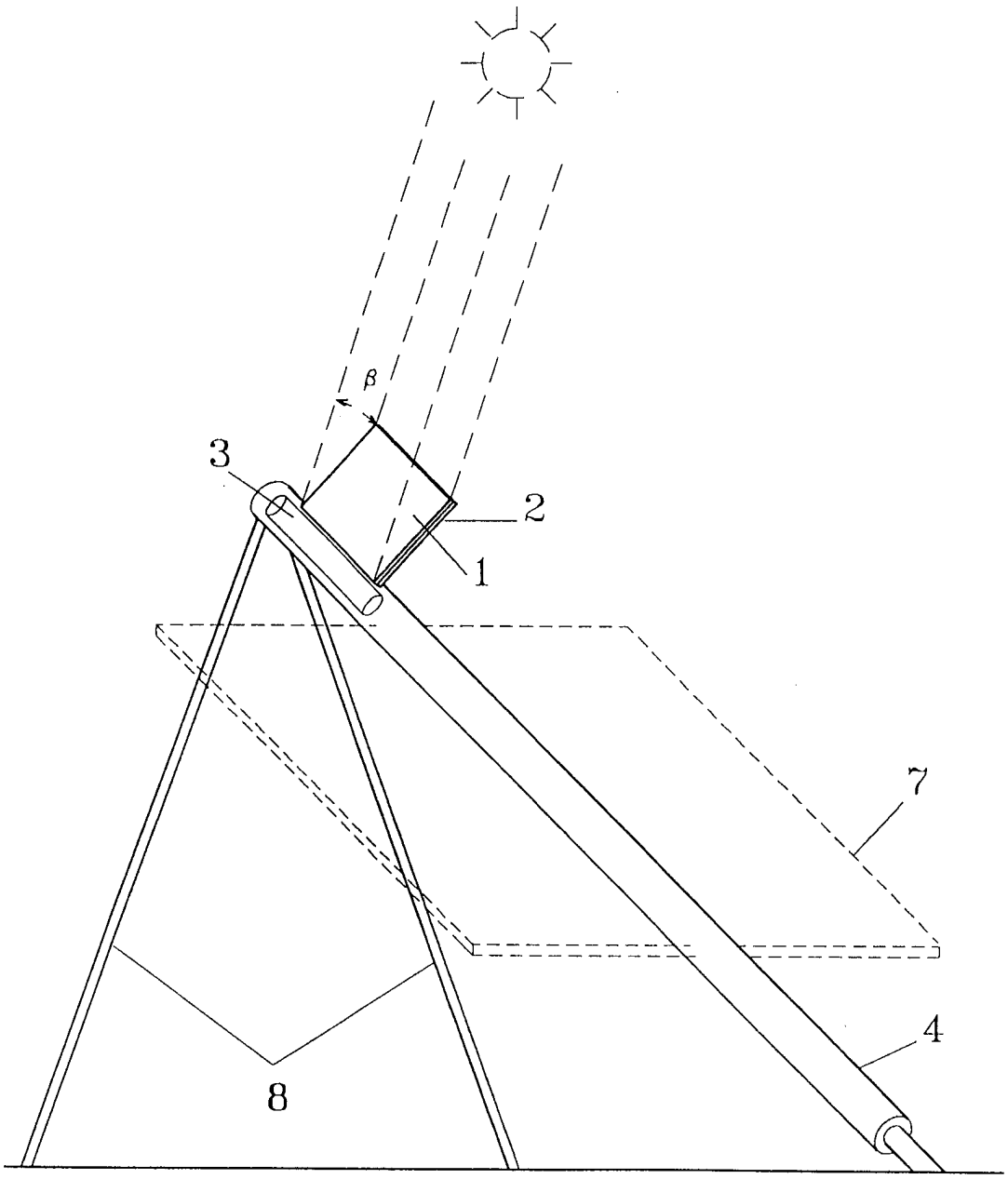

Fig. 5.

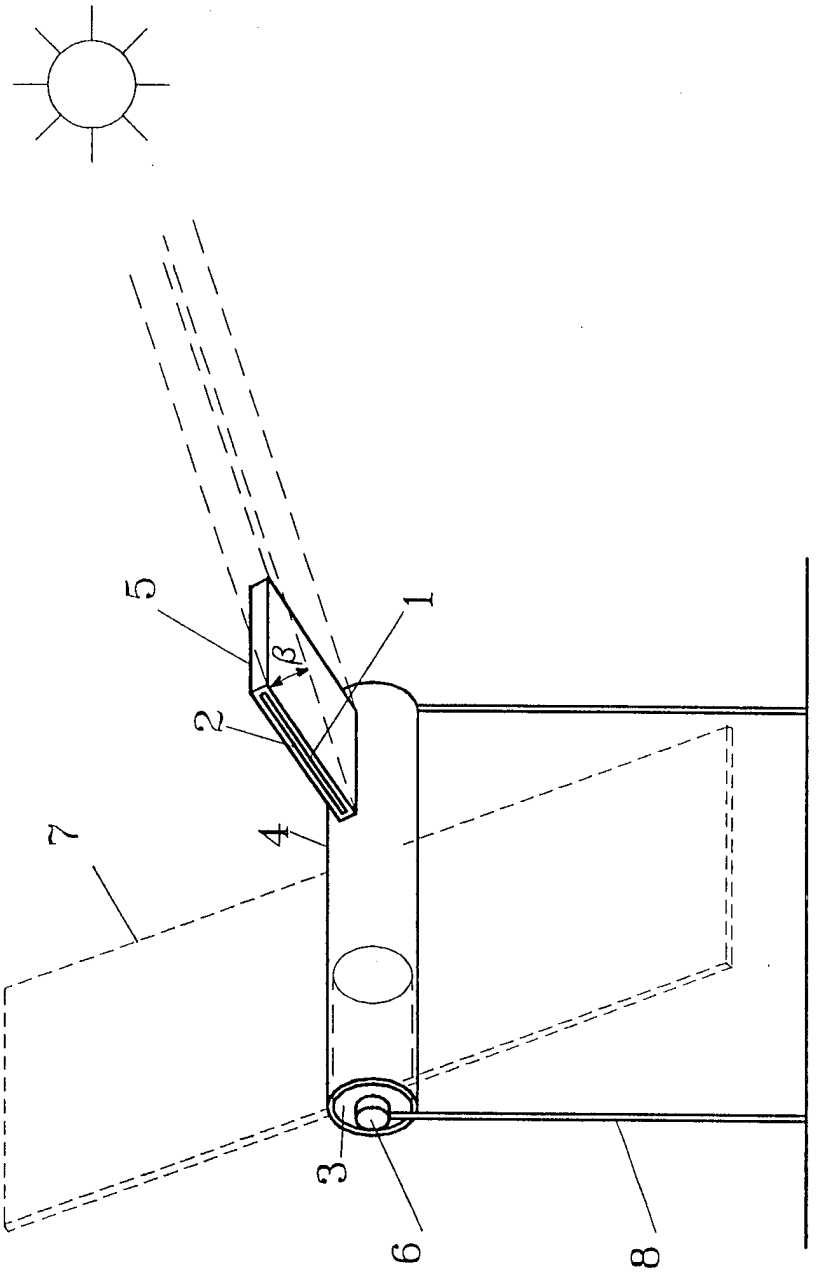

Fig. 6.

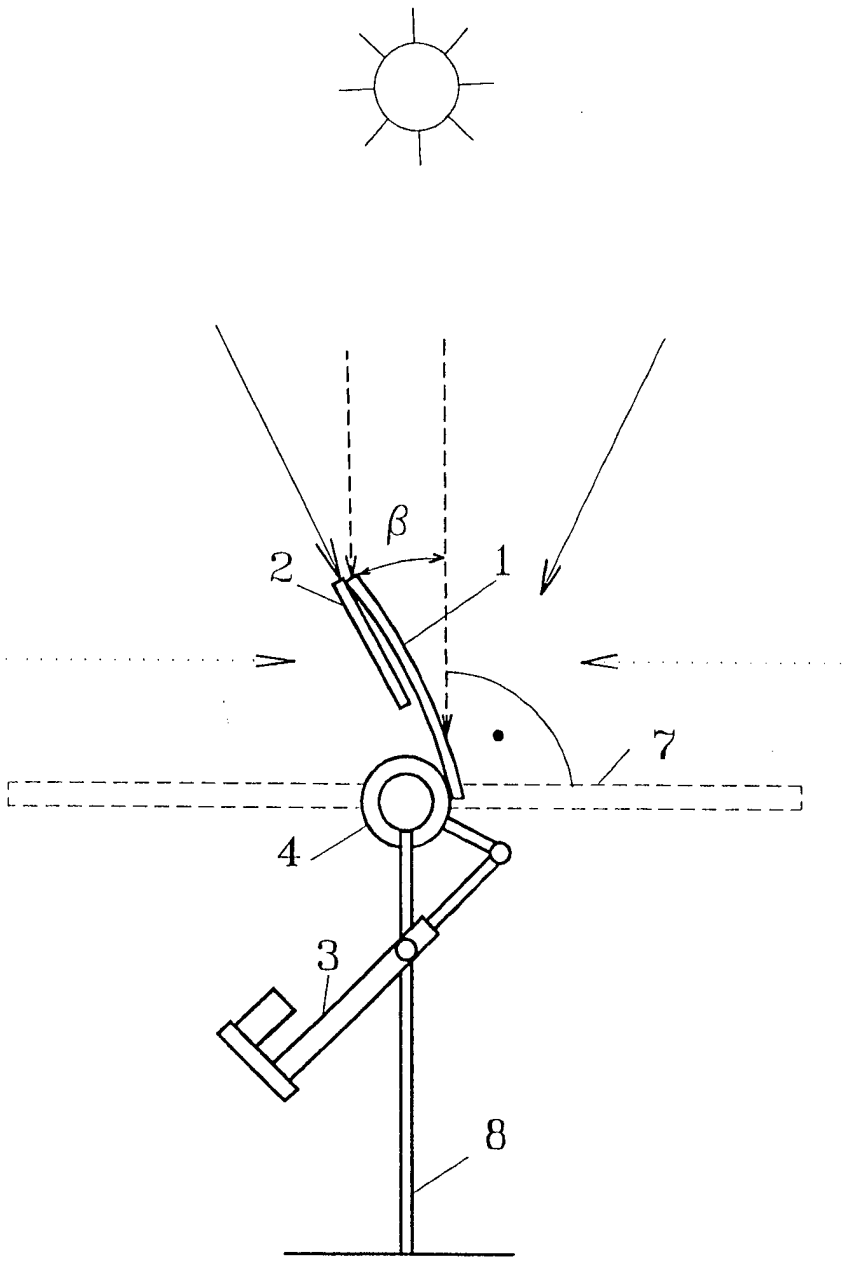

Fig. 7.

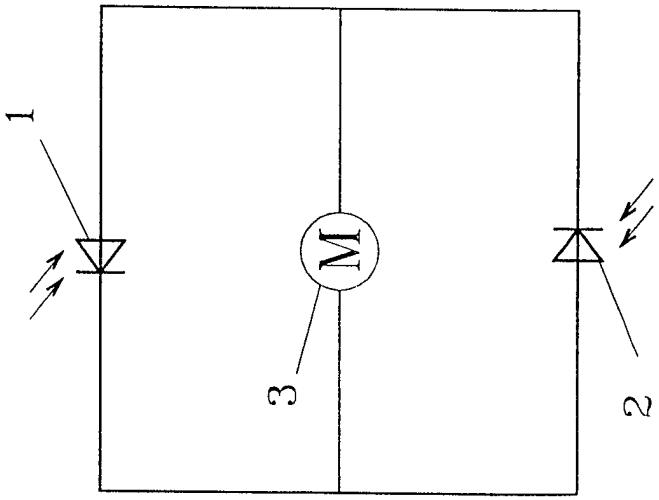

Fig. 8.

INTERNATIONAL SEARCH REPORT

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PCT/CZ 97/00042

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01S3/786

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 050 189 A (MORI KEI) 28 April 1982 see abstract see page 3, line 12 - page 10, line 16; figures 1-7	1
A	FR 2 403 525 A (LEONARD JEAN) 13 April 1979 see page 2, line 32 - page 6, line 2; figures 1-4	1
A	US 4 290 411 A (RUSSELL GEORGE F) 22 September 1981 see abstract see column 2, line 30 - column 6, line 19; figures 1-4	1

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[X] Further documents are listed in the continuation of box C.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 84 00068 A (ATLANTIS ENERGIE AG) 5 January 1984 see abstract see page 3, line 13 - page 13, line 14; figures 1-5	1
A	US 4 649 899 A (MOORE ROY A) 17 March 1987 see abstract see column 2, line 16 - column 5, line 26; figures 1-3	1
A	WO 93 13396 A (WATTSUN CORP) 8 July 1993 see abstract see page 7, line 24 - page 27, line 18; figures 1-9	1
A	US 4 328 417 A (HIMES ROGER) 4 May 1982 see abstract see column 1, line 52 - column 3, line 4; figures 1,2	1
A	DE 43 06 656 A (LINCKELMANN GEORG) 16 December 1993 see abstract see column 2, line 4 - column 3, line 16; figures 1-10	1

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Information on patent family members

Intern. ial Application No
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