

DESCRIPTION

Title of Invention:

SOLAR CELL MODULE AND INSTALLTION METHOD FOR SOLAR
5 CELL MODULE

Technical Field

[0001]

The present disclosure relates to a photovoltaic module and a method of installing a photovoltaic module.

10 **Background Art**

[0002]

One of power generation methods that use natural energy is solar power generation. Patent Literature 1 discloses a technique for enabling a photovoltaic module to be additionally installed without
15 removing an existing glass window. Specifically, in the technique disclosed in Patent Literature 1, the photovoltaic module is formed of a rectangular photovoltaic module body and a support member. Then the photovoltaic module body is disposed on the interior side of a building with respect to a glass window by using a support member.

20 **Citation List**

Patent Literature

[0003]

[Patent Literature 1] Japanese Unexamined Patent Application
Publication No. 2014-175402

25 **Summary of Invention**

Technical Problem

[0004]

However, in the technique disclosed in Patent Literature 1, the photovoltaic module is also disposed in an upper part of the interior
30 side of the glass window. This causes a problem that when a shadow created by the eave of the building is cast on the photovoltaic module, the amount of power generation in the photovoltaic module decreases.

[0005]

In view of the aforementioned problem, an object of the present

disclosure is to provide a photovoltaic module and a method of installing a photovoltaic module capable of appropriately installing a photovoltaic module on an interior side of a glass window of a building.

5 **Solution to Problem**

[0006]

A photovoltaic module and a method of installing a photovoltaic module according to one aspect of the present disclosure are as follows.

10 [0007]

[1]

A photovoltaic module installed on an interior side of a glass window of a building, in which

15 an eave is provided at a position of an upper outer part of the glass window of the building, and

the photovoltaic module is installed so as to satisfy

$$H1-(H2+h) \geq (L+t+d) \cdot \tan \theta \cdots (1),$$

20 where L denotes a horizontal distance from an outer surface of the glass window to an outer end of the eave, H1 denotes a vertical distance from a lower end of the eave to a lower end of the glass window, t denotes a thickness of the glass window, H2 denotes a height of the photovoltaic module, d denotes a surface spacing between the glass window and the photovoltaic module, h denotes a vertical distance from the lower end of the glass window to a lower end of the photovoltaic module, and θ denotes a solar altitude at the place where the building is built.

[0008]

[2]

30 The photovoltaic module according to [1], in which the θ is a solar altitude at solar noon on the winter solstice at the place where the building is built.

[0009]

[3]

The photovoltaic module according to [1], in which the θ is a

solar altitude at solar noon on the summer solstice at the place where the building is built.

[0010]

[4]

5 The photovoltaic module according to [1], in which the θ is an annual average solar altitude at solar noon at the place where the building is built.

[0011]

[5]

10 The photovoltaic module according to [1], in which the θ is a solar altitude at solar noon on the winter solstice or higher but equal to or lower than a solar altitude at solar noon on the summer solstice.

[0012]

[6]

15 The photovoltaic module according to any one of [1] to [5], in which an average solar absorption rate of the photovoltaic module is 30% or more but 90% or less.

[0013]

[7]

20 The photovoltaic module according to any one of [1] to [6], in which a surface spacing d between the glass window and the photovoltaic module satisfies $d \geq 0.5$ mm.

[0014]

[8]

25 The photovoltaic module according to any one of [1] to [7], in which when a vertical distance to a lower end of the photovoltaic module based on a lower end of a transmission region of the glass window is denoted by h_2 , $h_2 \geq 20$ mm is satisfied.

[0015]

30 [9]

The photovoltaic module according to any one of [1] to [8], in which

the photovoltaic module includes a plurality of photovoltaic cells disposed in a transparent plate-shaped member,

the plurality of photovoltaic cells are disposed in an array shape on a principal surface of the plate-shaped member in a horizontal direction and a vertical direction, and

the plurality of photovoltaic cells disposed in the horizontal direction are connected to one another using a wire.

[0016]

[10]

The photovoltaic module according to [9], in which

the plurality of photovoltaic cells are divided into a plurality of groups, a plurality of photovoltaic cells including a plurality of photovoltaic cells disposed in a horizontal direction and a plurality of photovoltaic cells disposed in a vertical direction forming a unit group,

the plurality of photovoltaic cells included in each of the groups are connected in series with one another using a horizontal wire that connects together the plurality of photovoltaic cells disposed in the horizontal direction and a vertical wire that connects together two photovoltaic cells adjacent to each other at an end of the horizontal direction, and

a negative side and a positive side of each of the groups are connected in parallel to each other by two bus bars extending in the vertical direction at both ends of the photovoltaic modules in the horizontal direction.

[0017]

[11]

The photovoltaic module according to any one of [1] to [10], wherein

when a refractive index of air is 1 and a refractive index of the glass window is denoted by n_2 , an amount of deviation ΔH of a solar light which is due to a difference between the refractive index of the air and the refractive index n_2 of the glass window is expressed by $\Delta H = t \cdot \tan \theta - t \cdot \tan \theta_2$, and H_2 in the Expression (1) is calculated as $H_2 + \Delta H$,

where θ_2 denotes an angle of refraction, and $\theta_2 = \text{Arcsin}(\sin \theta / n_2)$

is satisfied.

[0018]

[12]

The photovoltaic module according to any one of [1] to [11], in
 5 which the glass window is a multi-layered glass, and when a thickness
 of a glass plate on an outer side is denoted by t_1 , a thickness of a glass
 plate on an inner side is denoted by t_2 , a refractive index of air is 1,
 and a refractive index of the glass plates on the outer side and the
 inner side is denoted by n_2 , an amount of deviation ΔH of a solar light
 10 which is due to a difference between the refractive index of the air and
 the refractive index n_2 of the glass plate on the outer side and a
 difference between the refractive index of air and the refractive index
 n_2 of the glass plate on the inner side is expressed by $\Delta H = t_1 \cdot (\tan \theta -$
 $\tan \theta_2) + t_2 \cdot (\tan \theta - \tan \theta_2)$, and H_2 in the Expression (1) is calculated as
 15 $H_2 + \Delta H$,

where θ_2 denotes an angle of refraction, and $\theta_2 = \text{Arcsin}(\sin \theta / n_2)$
 is satisfied.

[0019]

[13]

20 The photovoltaic module according to any one of [1] to [12], in
 which

the photovoltaic module includes a plurality of photovoltaic
 cells disposed in a transparent plate-shaped member, and

the photovoltaic module has a configuration in which a
 25 transparent first plate-shaped member, an interlayer film, and a
 transparent second plate-shaped member are laminated, and the
 plurality of photovoltaic cells are sealed inside the interlayer film.

[0020]

[14]

30 A method of installing a photovoltaic module for installing the
 photovoltaic module on an interior side of a glass window of a
 building, wherein

an eave is provided at a position of an upper outer part of the
 glass window of the building, and

the photovoltaic module is installed so as to satisfy

$$H1-(H2+h) \geq (L+t+d) \cdot \tan\theta,$$

where L denotes a horizontal distance from an outer surface of the glass window to an outer end of the eave, H1 denotes a vertical distance from a lower end of the eave to a lower end of the glass window, t denotes a thickness of the glass window, H2 denotes a height of the photovoltaic module, d denotes a surface spacing between the glass window and the photovoltaic module, h denotes a vertical distance from the lower end of the glass window to a lower end of the photovoltaic module, and θ denotes a solar altitude at the place where the building is built.

Advantageous Effects of Invention

[0021]

According to the present disclosure, it is possible to provide a photovoltaic module and a method of installing a photovoltaic module capable of appropriately installing a photovoltaic module on an interior side of a glass window of a building.

Brief Description of Drawings

[0022]

Fig. 1 is a cross-sectional view showing a configuration example of a photovoltaic module according to an embodiment;

Fig. 2 is a plan view showing a configuration example of the photovoltaic module according to the embodiment;

Fig. 3 is a cross-sectional view in a cut-out line III-III of Fig. 2;

Fig. 4A is a cross-sectional view for describing a position where the photovoltaic module according to the embodiment is installed;

Fig. 4B is a front view for describing a position where the photovoltaic module according to the embodiment is installed;

Fig. 4C is a cross-sectional view for describing another example of a position where the photovoltaic module according to the embodiment is installed;

Fig. 4D is a cross-sectional view for describing another example of a position where the photovoltaic module according to the

embodiment is installed;

Fig. 5 is a cross-sectional view for describing a position where the photovoltaic module according to the embodiment is installed (the solar altitude at solar noon on the winter solstice);

5 Fig. 6 is a cross-sectional view for describing a position where the photovoltaic module according to the embodiment is installed (the solar altitude at solar noon on the summer solstice);

Fig. 7 is a cross-sectional view for describing a position where the photovoltaic module according to the embodiment is installed
10 (annual average solar altitude at solar noon);

Fig. 8 is a cross-sectional view showing a wiring example of the photovoltaic module according to the embodiment;

Fig. 9 is a cross-sectional view showing a wiring example of the photovoltaic module according to the embodiment;

15 Fig. 10 is a cross-sectional view showing another configuration example of the photovoltaic module according to the embodiment;

Fig. 11 is a cross-sectional view for describing an installation position in consideration of a refractive index of a glass window;

Fig. 12 is a cross-sectional view for describing the installation
20 position in consideration of the refractive index of the glass window;

Fig. 13 is a graph showing a relation between a surface spacing d between the glass window and the photovoltaic module, and a generated stress; and

Fig. 14 is a graph showing a relation between an edge-to-edge
25 distance between the glass window and the photovoltaic module, and the generated stress.

Description of Embodiments

[0023]

Hereinafter, with reference to the drawings, an embodiment will
30 be described.

Fig. 1 is a cross-sectional view showing a configuration example of a photovoltaic module according to the embodiment. As shown in Fig. 1, a photovoltaic module 10 according to this embodiment is installed on an interior side of a glass window 3 of a building 1. That

is, the building 1 includes an opening 5 for a window, and the glass window 3 is already provided in this opening 5 using a frame (window frame) 4. The photovoltaic module 10 according to this embodiment is disposed so as to be opposed to the glass window 3 that is already provided. The photovoltaic module 10 is fixed using a support member that is not shown. Further, an eave 2 is disposed at a position of an upper outer part of the glass window 3 of the building 1.

[0024]

Fig. 2 is a plan view showing a configuration example of the photovoltaic module according to the embodiment. Fig. 3 is a cross-sectional view in a cut-out line III-III of Fig. 2. As shown in Fig. 2, the photovoltaic module 10 according to this embodiment includes a plurality of photovoltaic cells 12 disposed in a transparent plate-shaped member 11. In other words, the plurality of photovoltaic cells 12 are disposed in an array shape in a horizontal direction and a vertical direction on a principal surface of the plate-shaped member 11.

[0025]

Fig. 2 shows, as an example, a configuration in which eight photovoltaic cells 12 are aligned in the horizontal direction and 12 photovoltaic cells 12 are aligned in the vertical direction in an array shape (i.e., 8×12 array shape). Note that the configuration shown in Fig. 2 is merely one example, and the number of photovoltaic cells 12 provided in the horizontal direction and that in the vertical direction may be any number. The photovoltaic cells 12 inside the photovoltaic module 10 are connected to each other by conductive interconnectors (wires).

[0026]

As shown in Fig. 3, the transparent plate-shaped member 11 included in the photovoltaic module 10 according to this embodiment includes a transparent plate 13, an interlayer film 14, and a transparent plate 15 laminated to one another. That is, the transparent plate 13 and the transparent plate 15 are bonded to each other using the interlayer film 14. The photovoltaic cell 12 is sealed between the

transparent plate 13 and the transparent plate 15, that is, inside the interlayer film 14.

[0027]

In this embodiment, the transparent plates 13 and 15 may each
5 be formed of a glass plate or a resin sheet. Therefore, the photovoltaic module 10 may have any one of (1) a configuration in which a glass plate is used for the transparent plate 13 and the transparent plate 15, (2) a configuration in which a resin sheet is used for the transparent plate 13 and the transparent plate 15, (3) a configuration in which a
10 resin sheet is used for the transparent plate 13 and a glass plate is used for the transparent plate 15, and (4) a configuration in which a glass plate is used for the transparent plate 13 and a resin sheet is used for the transparent plate 15.

[0028]

15 When glass plates are used for the transparent plates 13 and 15, the thickness of the transparent plates 13 and 15 is preferably 0.7 mm or more and 3.2 mm or less, more preferably 1.0 mm or more and 2.0 mm or less, and further preferably 1.3 mm or more and 2.0 mm or less. The transmittance of the transparent plates 13 and 15 is 70% or more.
20 For example, chemically tempered glass may be used for the transparent plates 13 and 15. When the chemically tempered glass is used, the weight of the transparent plates 13 and 15 can be reduced while maintaining the strength of the transparent plates 13 and 15. Therefore, workability when the photovoltaic module 10 is attached to
25 the support member or the like is improved. Further, the load of the support member that supports the photovoltaic module 10 can be reduced. In this embodiment, air-quenched tempered glass may be used for the transparent plates 13 and 15.

[0029]

30 When a resin sheet is used for the transparent plates 13 and 15, the thickness of the transparent plates 13 and 15 is preferably 0.03 mm or more and 3 mm or less, more preferably 0.05 mm or more and 1 mm or less, and further preferably 0.1 mm or more and 0.25 mm or less. By using the transparent plates 13 and 15, the weight of the

photovoltaic module 10 can be reduced. Accordingly, workability when the photovoltaic module 10 is attached to the support member or the like is improved. Further, the load of the support member that supports the photovoltaic module 10 can be reduced.

5 [0030]

When a resin sheet is used for the transparent plates 13 and 15, the resin sheet may include ethylene-tetrafluoroethylene copolymer (ETFE), ethylene-chlorotrifluoroethylene copolymer (ECTFE), polyvinyl fluoride (PVF), polyvinylidene fluoride (PVDF),
10 polyethylene terephthalate (PET), polystyrene (PS), polycarbonate (PC), or the like. Further, a combination of the above materials may be combined to form the resin sheet. For example, ETFE and PET may be combined to form the resin sheet.

[0031]

15 The interlayer film 14 is disposed so as to be held between the transparent plate 13 and the transparent plate 15. In other words, the transparent plate 13 and the transparent plate 15 are bonded to each other using the interlayer film 14. Specifically, when the photovoltaic module 10 is formed, the transparent plate 13, the interlayer film 14,
20 the photovoltaic cell 12, the interlayer film 14, and the transparent plate 15 are laminated in this order and this laminate is bonded by being heated and pressed to form the photovoltaic module 10. At this time, the interlayer film 14 disposed under the photovoltaic cell 12 and the interlayer film 14 disposed over the photovoltaic cells 12 are
25 heated and melt, and thus the interlayer film 14 of one layer is obtained in the completed photovoltaic module 10.

[0032]

The thickness of the interlayer film 14 is preferably 0.38 mm or more and 2.28 mm or less, more preferably 0.46 mm or more and 1.52
30 mm or less, and further preferably 0.76 mm or more and 1.2 mm or less. An ethylene-vinyl acetate copolymer (EVA) resin, a polyvinyl butyral (PVB) resin, an ionomer resin, cycloolefin polymer (COP), polyurethane, polyvinyl chloride (PVC), polyolefin elastomer (POE), olefin-based thermoplastic elastomer (TPO), or the like may be used as

the interlayer film 14. Further, the above materials may be combined with each other to form the interlayer film 14.

[0033]

The photovoltaic cells 12 can be formed using photovoltaic cells of a silicon-based monocrystalline type, a silicon-based polycrystalline type, an amorphous silicon type, a thin-film silicon type, a CIGS type, an organic thin-film type, a dye-sensitized type, or a perovskite type. As shown in Fig. 2, the shape of each of the photovoltaic cells 12 is a rectangular shape. For example, the shape of each of the photovoltaic cells 12 may be a square, a rectangular, or a circular shape. Further, single-sided light-receiving photovoltaic cells may be used, for example, as the photovoltaic cells 12. In this case, the photovoltaic cells 12 are disposed in such a way that the light-receiving surfaces thereof face outside, that is, toward the glass window 3. Further, double-sided light-receiving photovoltaic cells may be used for the photovoltaic cells 12.

[0034]

Further, in this embodiment, the photovoltaic module 10 may be formed using a film-like member. For example, the photovoltaic cells 12 may be disposed in the film-like member to form the photovoltaic module 10. The aforementioned resin sheet can be used, for example, as the film-like member. Further, in this case, organic thin-film type, dye-sensitized type, or perovskite type photovoltaic cells can be used for the photovoltaic cells 12. When the photovoltaic module 10 is formed by using a film-like member, the photovoltaic module 10 can be rolled up to be stored when it is not used, whereby the space can be saved. Further, the weight of the photovoltaic module 10 can be reduced.

[0035]

Fig. 4A is a cross-sectional view for describing a position where the photovoltaic module according to the embodiment is installed. Fig. 4B is a front view for describing a position where the photovoltaic module according to the embodiment is installed. In this embodiment, when a horizontal distance from the outer surface of the glass window

3 to the outer end of the eave 2 (the length of the eave 2) is denoted by L, a vertical distance from the lower end (point P) of the eave 2 to the lower end of the glass window 3 is denoted by H1, the thickness of the glass window 3 is denoted by t, the height of the photovoltaic module 10 is denoted by H2, a surface spacing between the glass window 3 and the photovoltaic module 10 is denoted by d, the vertical distance from the lower end of the glass window 3 to the lower end of the photovoltaic module 10 is denoted by h, and the solar altitude at the place where the building 1 is built is denoted by θ , the photovoltaic module is installed so as to satisfy the following Expression (1).

[0036]

$$H1 - (H2 + h) \geq (L + t + d) \cdot \tan \theta \cdots (1)$$

[0037]

When the photovoltaic module 10 is installed in such a way that Expression (1) is satisfied, it is possible to prevent or reduce the shadow created when a solar light 8 is blocked by the eave 2 from falling on the photovoltaic module 10. Therefore, by using this installation method, the photovoltaic module 10 can be appropriately installed on the interior side of the glass window 3 of the building 1.

[0038]

Note that, in this embodiment, the glass window 3 also includes the frame 4, and the lower end of the glass window 3 corresponds to the lower end of the frame 4. In the example shown in Fig. 4A, the lower end of the glass window 3 aligns with a floor surface 6. In this embodiment, the vertical distance H1 from the lower end of the eave 2 to the lower end of the glass window 3 may be expressed as the height H1 of the glass window 3.

[0039]

Further, as shown in Figs. 4A and 4B, when the vertical distance from the lower end of the glass window 3 (floor surface 6) to the top surface of the lower frame (window frame) 4 is denoted by h1, and the vertical distance from the top surface of the lower frame 4 to the lower end of the photovoltaic module 10, in other words, the vertical distance to the lower end of the photovoltaic module 10 based on the

lower end of the transmission region of the glass window 3 (i.e., the part of the glass) is denoted by h_2 , a relation $h = h_1 + h_2$ is satisfied. Further, as shown in Fig. 4B, the width of the photovoltaic module 10 is W , the edge-to-edge distance between the transmission region of the glass window 3 and the photovoltaic module 10 in the horizontal direction, that is, the distance from each of both ends of the transmission region of the glass window 3 in the horizontal direction to each of both ends of the photovoltaic module 10 in the horizontal direction is w .

10 [0040]

Further, Fig. 4A shows an example in which the body of the building 1 forms the eave 2. However, in this embodiment, as shown in Fig. 4C, the frame 4 may form the eave. In this case, the photovoltaic module is installed so as to satisfy the above Expression (1), assuming that the eave is the frame 4. That is, the photovoltaic module 10 is installed so as to satisfy the above Expression (1), where L denotes the horizontal distance from the outer surface of the glass window 3 to the outer end of the frame (eave) 4, H_1 denotes the vertical distance from the lower end (point P) of the frame (eave) 4 to the lower end of the glass window 3, t denotes the thickness of the glass window 3, H_2 denotes the height of the photovoltaic module 10, d denotes a surface spacing between the glass window 3 and the photovoltaic module 10, h denotes the vertical distance from the lower end of the glass window 3 to the lower end of the photovoltaic module 10, and θ denotes the solar altitude at the place where the building 1 is built.

[0041]

Note that, in this embodiment, a structure other than the aforementioned body (eave 2) or the frame 4 may form the eave. That is, in this embodiment, a structure that serves as the eave 2 on the outer surface of the glass window 3, i.e., a structure that shields the solar light 8, is defined as an eave.

[0042]

Further, in this embodiment, the glass window 3 may be a

window at waist height. That is, as shown in Fig. 4D, the glass
 window 3 may be installed on a window sill 7 installed on the floor
 surface 6. In this case, the photovoltaic module 10 is installed so as
 to satisfy the above Expression (1), where L denotes the horizontal
 5 distance (the length of the eave 2) from the outer surface of the glass
 window 3 to the outer end of the eave 2, H_1 denotes the vertical
 distance from the lower end (point P) of the eave 2 to the lower end of
 the glass window 3, t denotes the thickness of the glass window 3, H_2
 denotes the height of the photovoltaic module 10, d denotes a surface
 10 spacing between the glass window 3 and the photovoltaic module 10, h
 denotes the vertical distance from the lower end of the glass window 3
 to the lower end of the photovoltaic module 10, and θ denotes the solar
 altitude at the place where the building 1 is built. The same is applied
 to a case in which the configuration shown in Fig. 4C (when the frame
 15 4 forms the eave) and the configuration shown in Fig. 4D (when the
 glass window 3 is a window at waist height) are combined with each
 other.

[0043]

As one example, the length L of the eave 2 (the same is applied
 20 to a case in which the frame 4 forms the eave) is 0 to 1000 mm. For
 example, the length L of the eave 2 is less than 50 mm when an
 aluminum curtain wall (ACW) is used. The length L of the eave 2 is
 100 to 200 mm when there is no precast concrete (PC) placing
 sash/eave. The length L of the eave 2 is 300 to 1000 mm when there is
 25 a precast concrete (PC) placing sash/eave. When the length L of the
 eave 2 is 0, the outer wall of the building 1 and the outer surface of
 the glass window 3 are flush with each other.

[0044]

The thickness t of the glass window 3 is from 6 to 30 mm.
 30 When, for example, a single plate of glass is used, the thickness t of
 the glass window 3 is about from 6 to 10 mm. When a multi-layered
 glass is used, the thickness of each of two glass plates is 6 to 8 mm
 and the thickness of the air layer is about 6 to 14 mm. Therefore, the
 thickness of the multi-layered glass is about 18 to 30 mm.

[0045]

The height H1 of the glass window 3 is about 1500 to 3000 mm. When the glass window 3 is disposed on the entire surface, the height H1 of the glass window 3 is 2200 to 2500 mm. When the glass window 3 is a window at waist height, the height H1 of the glass window 3 is 1500 to 1800 mm.

[0046]

Note that the length L of the eave 2, the thickness t of the glass window 3, and the height H1 of the glass window 3 described above are merely examples, and these values vary depending on the building 1.

[0047]

The value of the solar altitude θ used in the above Expression (1) may be the solar altitude at solar noon on the winter solstice or higher but equal to or lower than the solar altitude at solar noon on the summer solstice. In this embodiment, the value of the solar altitude θ used in the above Expression (1) may be set as follows depending on the purpose of use of the photovoltaic module 10.

[0048]

When, for example, it is required to maximize an annual total power generation amount in the photovoltaic module 10, the solar altitude at solar noon on the winter solstice at the place where the building 1 is built may be used as the solar altitude θ . That is, as shown in Fig. 5, when the solar altitude at solar noon on the winter solstice is used as the solar altitude θ , the height H2 of the photovoltaic module 10 can be set high. It is therefore possible to allow the widest exposure of the photovoltaic module 10 to the solar light 8 on the winter solstice when the solar altitude at solar noon is the lowest throughout the year. Accordingly, the total power generation amount in the photovoltaic module 10 can be increased on the winter solstice when the solar altitude at solar noon is the lowest, whereby the annual total power generation amount in the photovoltaic module 10 can be increased.

[0049]

Further, when, for example, it is required to maximize the

annual power generation amount per unit area of the photovoltaic module 10, the solar altitude at solar noon on the summer solstice at the place where the building 1 is built may be used as the solar altitude θ . That is, as shown in Fig. 6, when the solar altitude at solar noon on the summer solstice is used as the solar altitude θ , the height H2 of the photovoltaic module 10 can be set low. Therefore, it can be ensured that the photovoltaic module 10 is not shaded at any time of the year, whereby the annual power generation amount per unit area of the photovoltaic module 10 can be increased. When, for example, it is desired to increase the Return On Investment (ROI), the value of the solar altitude θ is determined in such a way that the annual power generation amount per unit area increases.

[0050]

Further, when, for example, it is required to increase the annual total power generation amount as well while increasing the annual power generation amount per unit area of the photovoltaic module 10, the annual average solar altitude at solar noon at the place where the building 1 is built may be used as the solar altitude θ . That is, as shown in Fig. 7, when the annual average solar altitude at solar noon is used as the solar altitude θ , the height H2 of the photovoltaic module 10 can be set between the winter solstice (Fig. 5) and the summer solstice (Fig. 6). Therefore, the annual total power generation amount can be increased as well while increasing the annual power generation amount per unit area of the photovoltaic module 10.

[0051]

Instead of employing the aforementioned configuration, the solar altitude at solar noon on the vernal equinox or the solar altitude at solar noon on the autumnal equinox may be used, for example, as the solar altitude θ . In this case as well, the annual total power generation amount can be increased as well while increasing the annual power generation amount per unit area of the photovoltaic module 10.

[0052]

Note that, in this embodiment, the value of the solar altitude θ may be determined depending on the orientation of the building or the

presence or absence of a building nearby. When, for example, the building is not orientated toward the south or there is another building nearby, it is possible that the solar altitude at solar noon may not become the maximum solar altitude. In this case, the maximum solar altitude at a time of day when the glass window 3 is illuminated by the sun may be used as the value of the solar altitude θ . In this case as well, the value of the solar altitude θ may be determined in consideration of the solar altitude, which varies depending on the season, as described above. That is, the maximum solar altitude on the winter solstice (i.e., the maximum solar altitude at a time of day on the winter solstice when the glass window 3 is illuminated by the sun) or the maximum solar altitude on the summer solstice (i.e., the maximum solar altitude at a time of day on the summer solstice when the glass window 3 is illuminated by the sun) may be used as the value of the solar altitude θ .

[0053]

Table 1 shows the solar altitude at solar noon on the winter solstice, the solar altitude at solar noon on the summer solstice, and the annual average solar altitude at solar noon at each place.

[0054]

[Table 1]

Table 1

Place	Solar Altitude at Solar Noon on Winter Solstice	Solar Altitude at Solar Noon on Summer Solstice	Annual Average Solar Altitude at Solar Noon
Hokkaido (Sapporo)	23.5	70.4	47.3
Miyagi (Sendai)	28.3	75.2	52.1
Tokyo (Tokyo)	30.9	77.8	54.7
Aichi (Nagoya)	31.4	78.3	55.2
Osaka (Osaka)	31.9	78.8	55.7
Fukuoka (Fukuoka)	33.0	79.9	56.8

[0055]

Incidentally, in this embodiment, the closer the photovoltaic module 10 is to the glass window 3, the less the eave 2 affects on the photovoltaic module 10. However, when the photovoltaic module 10 is made too close to the glass window 3, the amount of heat transfer from

the photovoltaic module 10 to the glass window 3 increases. Further, since the space between the photovoltaic module 10 and the glass window 3 becomes narrow, the amount of the flow of the air in the space between the photovoltaic module 10 and the glass window 3 decreases and the heat dissipation amount decreases. Therefore, the difference between the temperature of an edge part on the surface of the glass window 3 and that of the other part increases, and thermal stress generated at the edge part increases.

[0056]

In this embodiment, in view of the aforementioned points, the average solar absorption rate of the photovoltaic module 10 is preferably 30% or more but 90% or less. At this time, it is more preferable that the lower-limit value be 40% or more, and more preferably 50% or more. More preferably, the upper-limit value is 80% or less, and further preferably 70% or less. By setting the upper-limit value of the average solar absorption rate of the photovoltaic module 10 in this range, power generation of the photovoltaic module 10 can be suppressed. Accordingly, the increase in the amount of heat transfer from the photovoltaic module 10 to the glass window 3 can be suppressed, whereby thermal stress generated in the edge part of the glass window 3 can be decreased. Further, when the lower-limit value of the average solar absorption rate is set to the above range, the decrease in the power generation amount which is due to the decrease in the area of the photovoltaic cells 12 can be suppressed.

Accordingly, by setting the range of the average solar absorption rate of the photovoltaic module 10 in the above range, thermal stress generated in the edge part of the glass window 3 can be decreased while securing the power generation amount in the photovoltaic module 10.

[0057]

Note that the average solar absorption rate is a solar absorption rate in the whole photovoltaic module 10, and is a value obtained by proportionally dividing the solar absorption rate of the part where the photovoltaic cells 12 are disposed and the solar absorption rate of the

other part (transmitting part) by their respective areas. The solar absorption rate can be calculated by using the following expression.

Solar absorption rate = 1 - (solar transmittance + solar reflectance)

5 The solar transmittance and the solar reflectance can be calculated from the value measured by a spectrophotometer based on JIS R 3106, Testing method for transmittance, reflectance and emissivity of flat glass and calculation of total solar energy transmittance of glazing.

10 [0058]

Further, in this embodiment, the surface spacing d between the glass window 3 and the photovoltaic module 10 is preferably set to $d \geq 0.5$ mm. More preferably, the surface spacing d is 1 mm or more, further preferably 5 mm or more, and most preferably 20 mm or more.

15 Further, the surface spacing d is preferably 300 mm or less, more preferably 200 mm or less, and further preferably 100 mm or less. By setting the range of the surface spacing d to this range, the increase in the amount of heat transfer from the photovoltaic module 10 to the glass window 3 can be suppressed while reducing the influence of the
20 eave 2 on the photovoltaic module 10. Accordingly, the thermal stress generated in the edge part of the glass window 3 can be decreased while increasing the power generation amount in the photovoltaic module 10.

[0059]

25 Further, in this embodiment, the vertical distance h_2 to the lower end of the photovoltaic module 10 based on the lower end of the transmission region of the glass window 3 is preferably set to satisfy $h_2 \geq 20$ mm. At this time, it is more preferable that the distance h_2 be 50 mm or more, and further preferably 100 mm or more. By setting the
30 range of the distance h_2 to this range, the increase in the temperature difference between the edge part of the glass window 3 and the other part can be suppressed. Therefore, thermal stress generated in the edge part of the glass window 3 can be decreased.

[0060]

Except for the case in which the solar altitude at solar noon on the summer solstice is used as the solar altitude θ , there are times when the photovoltaic module 10 is shaded by the eave 2. For example, when the solar altitude at solar noon on the winter solstice is used as the solar altitude θ , as shown in Fig. 5, the photovoltaic module 10 is shaded by the eave 2 during a period other than the winter solstice. When the photovoltaic module 10 is in shadow in this way, the power generation amount in the photovoltaic cells 12 disposed in the shaded part is reduced, and the power generation amount in the entire photovoltaic module 10 is reduced. Specifically, when the photovoltaic cells 12 are connected in series with one another, if the power generation amount in some of the photovoltaic cells 12 connected in series with one another is reduced, the power generation amount in the entire photovoltaic module 10 is reduced due to the effect of the photovoltaic cells 12 with reduced power generation amount.

[0061]

In particular, when the photovoltaic cells 12 disposed in the vertical direction are connected in series with one another, the photovoltaic cells 12 disposed on the upper side are shaded. When the power generation amount in the photovoltaic cells 12 disposed on the upper side is reduced, this gives an influence on the photovoltaic cells 12 disposed on the lower side, and the power generation amount in the entire photovoltaic module 10 is reduced.

[0062]

In order to solve the above problem, in this embodiment, as shown in Fig. 8, a plurality of photovoltaic cells 12 disposed in the horizontal direction are connected to one another using wires 31 to 34. Specifically, the plurality of photovoltaic cells 12 are divided into a plurality of groups D1-D4, a plurality of photovoltaic cells including a plurality of photovoltaic cells disposed in the horizontal direction and a plurality of photovoltaic cells disposed in the vertical direction forming a unit group. Then the plurality of photovoltaic cells 12 included in each of the groups D1-D4 are connected in series with one

another using a horizontal wire that connects together a plurality of photovoltaic cells 12 disposed in the horizontal direction and a vertical wire that connects together two photovoltaic cells adjacent to each other at an end of the horizontal direction.

5 [0063]

For example, in the group D1, the plurality of photovoltaic cells 12 disposed in the horizontal direction are connected to one another using a horizontal wire 31h. Further, two photovoltaic cells adjacent to each other at an end of the horizontal direction are connected to one
10 another using a vertical wire 31v. Accordingly, the plurality of photovoltaic cells 12 in the group D1 are connected in series with one another using the horizontal wire 31h and the vertical wire 31v.

[0064]

The negative side and the positive side of each of the groups
15 D1-D4 are connected in parallel to each other using two bus bars 21 and 22 extending in the vertical direction at both ends of the photovoltaic module 10 in the horizontal direction. That is, the negative side of the wire 31 in the group D1 is connected to the bus bar wire 21 and the positive side thereof is connected to the bus bar
20 wire 22. The negative side of the wire 32 in the group D2 is connected to the bus bar wire 21 and the positive side thereof is connected to the bus bar wire 22. The negative side of the wire 33 in the group D3 is connected to the bus bar wire 21 and the positive side thereof is connected to the bus bar wire 22. The negative side of the wire 34 in
25 the group D4 is connected to the bus bar wire 21 and the positive side thereof is connected to the bus bar wire 22. Accordingly, the photovoltaic cells 12 in each of the groups D1-D4 are connected in parallel to each other using the two bus bars 21 and 22. The two bus bars 21 and 22 are taken outside from a junction box 23.

30 [0065]

As described above, in this embodiment, the photovoltaic cells 12 included in the photovoltaic module 10 are divided into the plurality of groups D1-D4. Then the photovoltaic cells 12 included in each of the groups D1-D4 are connected in series with one another, and

the negative side and the positive side of the photovoltaic cells 12 in each of the groups D1-D4 are connected in parallel to each other using the two bus bars 21 and 22, respectively. Accordingly, as shown in Fig. 9, even when the shadow created by the eave 2 is cast on the upper group D4 of the photovoltaic module 10 and the power generation amount in the group D4 is reduced, it is possible to prevent the power generation amount in the other groups D1 to D3 from being affected.

[0066]

Further, Fig. 8 shows a configuration example in which the number of photovoltaic cells 12 included in each of the groups D1-D4 in the vertical direction is three. However, in this embodiment, the number of photovoltaic cells 12 included in each of the groups D1-D4 in the vertical direction is not limited to three, and may be any number. Further, in this embodiment, in order to make voltage values output from the respective groups D1-D4 the same, the number of photovoltaic cells 12 included in each of the groups D1-D4 is preferably made the same.

[0067]

For example, in this embodiment, the value of H2 obtained by using the solar altitude at solar noon on the summer solstice as the solar altitude θ and the height of the group D1 may be made the same. In other words, the boundary of the shadow at noon on the summer solstice may be aligned with the boundary part between the group D1 and the group D2. This configuration allows the photovoltaic cells 12 in the group D1 to constantly generate power throughout the year. At this time, the number of photovoltaic cells 12 in each of the other groups D2-D4 and the number of photovoltaic cells 12 in the group D1 may be made the same.

[0068]

In the photovoltaic module 10 shown in Fig. 8, the number of photovoltaic cells 12 included in each of the groups D1-D4 in the vertical direction is preferably made the same. Therefore, in this embodiment, the number of photovoltaic cells 12 included in each of the groups D1-D4 in the vertical direction is determined, and then the

solar altitude θ may be determined in view of the boundary part of each of the groups D1-D4.

[0069]

Fig. 10 is a cross-sectional view showing another configuration example of the photovoltaic module according to this embodiment. As described above, in the photovoltaic module according to this embodiment, except for the case in which the solar altitude at solar noon on the summer solstice is used as the solar altitude θ , there are times when the photovoltaic module 10 is shaded by the eave 2. Since the photovoltaic cells 12 in shadow do not contribute to power generation, photovoltaic cells 12 may not be disposed in such a place. However, it may be desired to dispose photovoltaic cells 12 also in the place in shadow in order to achieve design consistency with photovoltaic modules installed in other places. In this case, like in a photovoltaic module 10a as shown in Fig. 10, dummy cells 16 may be disposed at a place of the photovoltaic module 10a in shadow. By disposing the dummy cells 16, the design quality of the photovoltaic module 10a can be improved without disposing the photovoltaic cells 12.

[0070]

Next, with reference to Figs. 11 and 12, a position where the photovoltaic module 10 is installed in view of the refractive index of the glass window 3 will be described. First, with reference to Fig. 11, a case in which the glass window 3 is a single plate of glass will be described.

[0071]

When the solar light 8 is incident on the glass window 3, the solar light 8 is refracted due to a difference between a refractive index of air and that of the glass window 3. Therefore, a solar light 8a after passing through the glass window 3 is deviated with respect to the traveling direction of the solar light 8. The amount of deviation of the solar light at this time is denoted by ΔH . Then, when the refractive index of air is 1 and the refractive index of the glass window 3 is denoted by n_2 , the amount of deviation ΔH of the solar light which is

due to the difference between the refractive index of air and the refractive index n_2 of the glass window 3 is expressed by the following Expression (2). Therefore, by calculating H_2 in the above Expression (1) as $H_2 + \Delta H$, the installation position can be determined in view of the amount of deviation ΔH of the solar light.

$$\Delta H = t \cdot \tan \theta - t \cdot \tan \theta_2 \cdots \text{Expression (2)}$$

(where θ_2 denotes the angle of refraction, and $\theta_2 = \text{Arcsin}(\sin \theta / n_2)$ is satisfied)

[0072]

As an example, when it is assumed that the refractive index n_2 of the glass window 3 is 1.52, the solar altitude θ is 77.8 degrees, and the thickness t of the glass window 3 is 10 mm, the value of the amount of deviation ΔH is 37.9 mm.

[0073]

Next, with reference to Fig. 12, a case in which the glass window 3 is a multi-layered glass will be described. When the glass window 3 is a multi-layered glass, the solar light 8 passes through two glass plates, namely, a glass plate 3_1 on the outer side and a glass plate 3_2 on the inner side. At this time, the solar light 8 is refracted twice due to the difference in the refractive index of the air and that of the glass plates 3_1 and 3_2. Therefore, a solar light 8b after passing through the glass window 3 is deviated with respect to the traveling direction of the solar light 8. The amount of deviation of the solar light at this time is denoted by ΔH . When the thickness of the glass plate 3_1 on the outer side is denoted by t_1 , the thickness of the glass plate 3_2 on the inner side is denoted by t_2 , the refractive index of air is 1, and the refractive index of the glass plate 3_1 on the outer side and the glass plate 3_2 on the inner side is denoted by n_2 , the amount of deviation ΔH of the solar light due to the difference between the refractive index of air and the refractive index n_2 of the glass plate 3_1 on the outer side, and the difference between the refractive index of air and the refractive index n_2 of the glass plate 3_2 on the inner side is expressed by the following Expression (3). Therefore, by calculating H_2 in the above Expression (1) as $H_2 + \Delta H$, the installation

position can be determined in consideration of the amount of deviation ΔH of the solar light.

$$\Delta H = \Delta H_1 + \Delta H_2$$

$$= t_1 \cdot (\tan \theta - \tan \theta_2) + t_2 \cdot (\tan \theta - \tan \theta_2) \cdots \text{Expression (3)}$$

5 (where θ_2 denotes the angle of refraction, and

$\theta_2 = \text{Arcsin}(\sin \theta / n_2)$ is satisfied)

[0074]

As one example, when the refractive index n_2 of the glass plates 3_1 and 3_2 is set to 1.52, the solar altitude θ is set to 77.8 degrees,
10 and the thicknesses t_1 and t_2 of the glass plates 3_1 and 3_2 are set to 6 mm, the value of the amount of deviation ΔH is 45.4 mm.

[0075]

According to the embodiment described above, it is possible to provide a photovoltaic module and a method of installing a
15 photovoltaic module capable of appropriately installing a photovoltaic module on an interior side of a glass window of a building.

Examples

[0076]

<Simulations on Relation between Installation Position and Module
20 Output>

By using the following method, simulations on a position where the photovoltaic module is installed and the module output were conducted. The length L of the eave 2, the thickness t of the glass window 3, the surface spacing d between the glass window 3 and the
25 photovoltaic module 10, the vertical distance (height of the glass window 3) H_1 from the lower end (point P) of the eave 2 to the lower end of the glass window 3, the vertical distance h from the lower end of the glass window 3 to the lower end of the photovoltaic module 10, and the solar altitude θ shown in Fig. 4A were set to values shown in
30 Table 2, and the allowable module height was obtained by using the Expression (1). Then the height H_2 of the photovoltaic module 10 was determined to be within the obtained allowable module height.

[0077]

After that, a module rated output (W), an annual module average

output (W), and an annual module average output per unit (W/m^2) of the photovoltaic module 10 were obtained by simulations. Note that the annual module average output (W) corresponds to the above annual total power generation amount in the photovoltaic module 10, and the

5 annual module average output per unit (W/m^2) corresponds to the above annual power generation amount per unit area of the photovoltaic module 10.

[0078]

Further, calculations were performed assuming that each of the

10 photovoltaic cells 12 included in the photovoltaic module 10 was a square having a side length of 158.75 (mm), the cell rated output thereof was 5.645 (Wp/piece) or 223.994 (Wp/m^2), the cell area rate thereof was 70%, and the module output thereof was 156.8 (Wp/m^2). Further, the width of the glass window 3 was set to 1800 mm and the

15 width of the photovoltaic module 10 was set to 1700 mm. As the solar altitude θ , the solar altitude at solar noon on the winter solstice in Tokyo: 30.9 degrees, the annual average solar altitude at solar noon: 54.7 degrees, or the solar altitude at solar noon on the summer solstice: 77.8 degrees, was used. Table 2 shows results of the

20 simulations.

[0079]

[Table 2]

Table 2

	L[mm]	t[mm]	d[mm]	H1[mm]	h[mm]	θ [deg.]	Allowable Module Height [mm]	H2[mm]	Module Rated Output [W]	Module Average Output [W]	Module Average Output Per Unit [W/m ²]
Example 1	50	10	10	2500	50	30.9	2408.1	2400	639.7	616.7	151.1
Example 2	50	10	10	2500	50	54.7	2351.1	2350	626.4	611.7	153.1
Example 3	50	10	10	2500	50	77.8	2126.2	2120	565.1	565.1	156.8
Example 4	50	10	100	2500	50	—	—	2400	639.7	570.5	139.8
Example 5	50	10	100	2500	50	30.9	2354.2	2350	626.4	570.4	142.8
Example 6	50	10	100	2500	50	54.7	2224.0	2220	591.7	558.3	147.9
Example 7	50	10	100	2500	50	77.8	1710.0	1700	453.1	453.1	156.8
Example 8	50	10	100	2500	500	—	—	2400	639.7	450.5	110.4
Example 9	50	10	100	2500	500	30.9	1904.2	1900	506.5	450.5	139.5
Example 10	50	10	100	2500	500	54.7	1774.0	1770	471.8	438.4	145.7
Example 11	50	10	100	2500	500	77.8	1260.0	1250	333.2	333.2	156.8
Example 12	300	10	10	2500	50	—	—	2400	639.7	487.9	119.6
Example 13	300	10	10	2500	50	30.9	2258.5	2250	599.7	487.8	127.5
Example 14	300	10	10	2500	50	54.7	1998.0	1990	530.4	463.6	137.0
Example 15	300	10	10	2500	50	77.8	969.9	960	255.9	255.9	156.8
Example 16	50	10	30	2500	50	30.9	2396.1	2350	626.4	570.4	142.8
Example 17	50	10	30	2500	50	54.7	2322.9	2300	613.1	567.3	145.1
Example 18	50	10	30	2500	50	77.8	2033.7	2000	533.1	521.1	153.3
Example 19	50	10	50	2500	50	30.9	2384.2	2350	626.4	570.4	142.8
Example 20	50	10	50	2500	50	54.7	2294.6	2250	599.7	562.1	147.0
Example 21	50	10	50	2500	50	77.8	1941.2	1900	506.5	500.5	154.9
Example 22	50	10	200	2500	50	30.9	2294.4	2250	599.7	562.1	147.0
Example 23	50	10	200	2500	50	54.7	2082.8	2050	546.4	530.7	152.3
Example 24	50	10	200	2500	50	77.8	1247.5	1200	319.9	319.9	156.8

[0080]

As shown in Table 2, in Example 1, the solar altitude θ was set to 30.9 degrees, which is the solar altitude at solar noon on the winter solstice. In Example 2, the solar altitude θ was set to 54.7 degrees, which is the annual average solar altitude at solar noon. In Example 3, the solar altitude θ was set to 77.8 degrees, which is the solar altitude at solar noon on the summer solstice. As a result, the allowable module height was 2408.1 (mm) in Example 1, 2351.1 (mm) in Example 2, and 2126.2 (mm) in Example 3. Therefore, the height H2 of the photovoltaic module 10 was set to 2400 (mm) in Example 1, 2350 (mm) in Example 2, and 2120 (mm) in Example 3. In the photovoltaic modules 10 according to Examples 1 to 3, the module rated output (W) and the module average output (W) were the highest in Example 1. It can be considered that the reason therefor is that, since the solar altitude at solar noon on the winter solstice, 30.9 degrees, was used as

the solar altitude θ in Example 1, the height H2 of the photovoltaic module 10 was able to be set high. That is, in Example 1, the total amount of the solar light reaching the photovoltaic module 10 becomes large throughout the year, and thus the module rated output (W) and the module average output (W) became high.

[0081]

On the other hand, in Example 3, the module rated output (W) and the module average output (W) were the lowest. It can be considered that the reason therefor is that, since the solar altitude at solar noon on the summer solstice: 77.8 degrees, was used as the solar altitude θ in Example 3, the height H2 of the photovoltaic module 10 was set to be low. Focusing on the module average output per unit (W/m^2), the largest value was obtained in Example 3. It can be considered that the reason therefor is that, since the height H2 of the photovoltaic module 10 was set low in Example 3, it can be ensured that the photovoltaic module 10 is not shaded at any time of the year, whereby the annual module average output per unit area of the photovoltaic module 10 was able to be set high.

[0082]

In Examples 4 to 7, the surface spacing d between the glass window 3 and the photovoltaic module 10 was made larger than that in Examples 1 to 3. When the surface spacing d is made large as in Examples 5 to 7, the allowable module height becomes lower than those in Examples 1 to 3 where the surface spacing d is small. Therefore, the height H2 of the photovoltaic module 10 in each of Examples 5 to 7 is set lower than the height H2 of the photovoltaic module 10 in each of Examples 1 to 3. Therefore, in Examples 5 to 7, the values of the module rated output (W), the module average output (W), and the module average output per unit (W/m^2) were lower than those in Examples 1 to 3. Further, the values of the module rated output (W), the module average output (W), and the module average output per unit (W/m^2) in Examples 5 to 7 showed a similar trend to those in Examples 1 to 3. In Example 4, the height H2 of the photovoltaic module 10 is set to 2400 (mm) for the sake of comparison.

Since the surface spacing d is made larger in Example 4 than that in Example 1, the values of the module average output (W) and the module average output per unit (W/m^2) became lower than those in Example 1.

5 [0083]

In Examples 8 to 11, the distance h to the lower end of the photovoltaic module 10 is made larger than that in Examples 4 to 7. When the distance h is made large as in Examples 9 to 11, the allowable module height becomes lower than those in Examples 5 to 7
 10 where the distance h is small. Therefore, the height $H2$ of the photovoltaic module 10 in each of Examples 9 to 11 is set to be lower than the height $H2$ of the photovoltaic module 10 in each of Examples 5 to 7. Therefore, in Examples 9 to 11, the values of the module rated output (W), the module average output (W), and the module average
 15 output per unit (W/m^2) were lower than those in Examples 5 to 7. Further, the values of the module rated output (W), the module average output (W), and the module average output per unit (W/m^2) in Examples 9 to 11 showed a similar trend to those in Examples 5 to 7. In Example 8, for the sake of comparison, the height $H2$ of the
 20 photovoltaic module 10 was set to 2400 (mm). Since the distance h to the lower end of the photovoltaic module 10 is set larger in Example 8 than that in Example 4, the values of the module average output (W) and the module average output per unit (W/m^2) were lower than those in Example 4.

25 [0084]

The length L of the eave 2 is made larger in Examples 12 to 15 than that in Examples 1 to 3. When the length L of the eave 2 is made large as in Examples 13 to 15, the allowable module height becomes lower than that in Examples 1 to 3 where the length L of the eave 2 is
 30 small. Therefore, the height $H2$ of the photovoltaic module 10 in each of Examples 13 to 15 is set to be lower than the height $H2$ of the photovoltaic module 10 in each of Examples 1 to 3. Therefore, in Examples 13 to 15, the values of the module rated output (W), the module average output (W), and the module average output per unit

(W/m²) were lower than those in Examples 1 to 3. Further, the values of the module rated output (W), the module average output (W), and the module average output per unit (W/m²) in Examples 13 to 15 showed a similar trend to those in Examples 1 to 3. In Example 12, the height H2 of the photovoltaic module 10 is set to 2400 (mm) for the sake of comparison. Since the length L of the eave 2 is larger in Example 12 than that in Example 1, the values of the module average output (W) and the module average output per unit (W/m²) were lower than those in Example 1.

10 [0085]

The surface spacing d between the glass window 3 and the photovoltaic module 10 was larger in Examples 16 to 24 than that in Examples 1 to 3. Specifically, the surface spacing d was set to 30 mm in Examples 16 to 18, the surface spacing d was set to 50 mm in Examples 19 to 21, and the surface spacing d was set to 200 mm in Examples 22 to 24. The other conditions were set to be similar to those in Examples 1 to 3. Note that the solar altitudes θ in Examples 16 to 18 respectively correspond to the solar altitudes θ in Examples 1 to 3, the solar altitudes θ in Examples 19 to 21 respectively correspond to the solar altitudes θ in Examples 1 to 3, and the solar altitudes θ in Examples 22 to 24 respectively correspond to solar altitudes θ in Examples 1 to 3.

[0086]

When the surface spacing d is made large as in Examples 16 to 24, the allowable module height becomes lower than those in Examples 1 to 3 where the surface spacing d is small. Therefore, the height H2 of the photovoltaic module 10 in each of Examples 16 to 24 is set lower than the height H2 of the photovoltaic module 10 in each of Examples 1 to 3. Therefore, in Examples 16 to 24, the values of the module rated output (W), the module average output (W), and the module average output per unit (W/m²) were lower than those in Examples 1 to 3. Further, the values of the module rated output (W), the module average output (W), and the module average output per unit (W/m²) in Examples 16 to 24 showed a similar trend to those in

Examples 1 to 3.

[0087]

From the aforementioned results, the smaller the surface spacing d between the glass window 3 and the photovoltaic module 10, the greater the values of the module average output (W) and the module average output per unit (W/m^2). Further, the smaller the distance h to the lower end of the photovoltaic module 10, the greater the values of the module average output (W) and the module average output per unit (W/m^2). Further, the smaller the solar altitude θ , the greater the value of the module average output (W). Further, the greater the solar altitude θ , the smaller the value of the module average output per unit (W/m^2).

[0088]

<Simulations On Relation between Installation Position and Generated Stress>

By using the following method, simulations on a relation between a position where the photovoltaic module is installed and a generated stress were conducted. The length H_1 of the long side (vertical direction) of the glass window 3 was set to 2400 (mm) and the length of the short side (horizontal direction) thereof was set to 1800 (mm). The thickness t of the glass window 3 was set to 28 mm, which is a total of glass: 8 mm, air layer; 12 mm, and glass: 8 mm. The surface spacing d between the glass window 3 and the photovoltaic module 10 was set as shown in Table 3. An edge-to-edge distance between the glass window 3 and the photovoltaic module 10 in the vertical distance, that is, the vertical distance h_2 to the lower end of the photovoltaic module 10 based on the lower end of the transmission region of the glass window 3 was set as shown in Table 3. An edge-to-edge distance w (see Fig. 4B) between the glass window 3 and the photovoltaic module 10 in the horizontal direction, that is, the distance w from each of both ends of the glass window 3 in the horizontal direction to each of both ends of the photovoltaic module 10 in the horizontal direction was set as shown in Table 3. Note that the edge-to-edge distance h_2 and the edge-to-edge distance w were set to be the

same.

[0089]

The height H2 of the photovoltaic module 10 was set to 1440 (mm), the width W thereof was set to 600 (mm), and the area thereof was set to 0.864 (m²). The number of photovoltaic cells 12 included in the photovoltaic module 10 was set to 24. Each of the photovoltaic cells 12 was a square with a side length of 158.75 (mm). The transmittance of the glass forming the photovoltaic module 10 was set to 92% and the solar absorption rate was set to 16.2%. The solar absorption rate of the photovoltaic cells 12 was set to 92.4%. The power generation area rate of the photovoltaic module 10 was set to 70% and the power generation area was set to 0.605 (m²). The average transmittance of the photovoltaic module 10 was set to 27.6% and the average solar absorption rate was set to 69.5%.

15 [0090]

The amount of solar radiation incident on the photovoltaic module 10 was set to 825 W/m², the outside temperature of the building where the photovoltaic module 10 was installed was set to 5°C, the indoor temperature was set to 20°C, the heat transmittance on the outer side of the building was set to 15.1 W/m²K, the heat transmittance on the inner side of the building was set to 8.0 W/m²K, and the temperature of the glass window 3 was set to 10.2°C.

Simulations were conducted under these conditions and the stress generated in the glass window 3 was obtained. Table 3 shows results of simulations. Further, Fig. 13 shows a relation between the surface spacing d and the generated stress. Further, Fig. 14 shows a relation between an edge-to-edge distance (h2, w) between the glass window 3 and the photovoltaic module 10, and the generated stress.

[0091]

30 [Table 3]

Table 3

	Number of Cells	Window Size (Long Side) H1(mm)	Window Size (Short Side) (mm)	Surface Spacing d(mm)	Edge-to-Edge Distance w (mm)	Edge-to-Edge Distance h2(mm)	Generated Stress (MPa)
Example 25	24	2400	1800	0	10	10	22.26
Example 26	24	2400	1800	0.5	10	10	17.91
Example 27	24	2400	1800	1	10	10	17.10
Example 28	24	2400	1800	5	10	10	14.78
Example 29	24	2400	1800	10	10	10	13.51
Example 30	24	2400	1800	15	10	10	12.77
Example 31	24	2400	1800	30	10	10	11.49
Example 32	24	2400	1800	100	10	10	8.74
Example 33	24	2400	1800	0	20	20	22.21
Example 34	24	2400	1800	0.5	20	20	17.97
Example 35	24	2400	1800	1	20	20	17.33
Example 36	24	2400	1800	5	20	20	14.77
Example 37	24	2400	1800	10	20	20	13.40
Example 38	24	2400	1800	15	20	20	12.65
Example 39	24	2400	1800	30	20	20	11.49
Example 40	24	2400	1800	100	20	20	9.42
Example 41	24	2400	1800	0	50	50	21.54
Example 42	24	2400	1800	0.5	50	50	17.66
Example 43	24	2400	1800	1	50	50	17.20
Example 44	24	2400	1800	5	50	50	14.54
Example 45	24	2400	1800	10	50	50	13.16
Example 46	24	2400	1800	15	50	50	12.42
Example 47	24	2400	1800	30	50	50	11.32
Example 48	24	2400	1800	100	50	50	9.50
Example 49	24	2400	1800	0	100	100	20.17
Example 50	24	2400	1800	0.5	100	100	16.64
Example 51	24	2400	1800	1	100	100	16.27
Example 52	24	2400	1800	5	100	100	13.72
Example 53	24	2400	1800	10	100	100	12.41
Example 54	24	2400	1800	15	100	100	11.71
Example 55	24	2400	1800	30	100	100	10.71
Example 56	24	2400	1800	100	100	100	9.19

[0092]

As shown in Table 3 and Fig. 13, the greater the surface spacing d between the glass window 3 and the photovoltaic module 10, the smaller the stress generated in the glass window 3. It can be considered that the reason therefor is that the greater the surface spacing d between the glass window 3 and the photovoltaic module 10, the greater the heat dissipation amount in the space between the photovoltaic module 10 and the glass window 3. Further, as shown in Fig. 14, the greater the edge-to-edge distance between the glass window 3 and the photovoltaic module 10, the smaller the stress generated in the glass window 3. It can be considered that the reason

therefor is because the closer the edge of the photovoltaic module 10 approaches the center of the glass window 3 (see Fig. 4B), the smaller the influence of the heat generated in the glass window 3 due to the photovoltaic module 10.

5 [0093]

While the present invention has been described in view of the aforementioned embodiment, the present invention is not limited to the configurations of the above embodiment. As a matter of course, the present invention includes various variations, modifications, and
10 combinations that may be made by one skilled in the art without the scope of the invention set forth in the claims of the present application.

[0094]

This application is based upon and claims the benefit of priority
15 from Japanese patent application No. 2023-158957, filed on September 22, 2023, the disclosure of which is incorporated herein in its entirety by reference.

Reference Signs List

[0095]

20	1	BUILDING
	2	EAVE
	3	GLASS WINDOW
	4	FRAME
	5	OPENING
25	6	FLOOR SURFACE
	7	WINDOW SILL
	8	SOLAR LIGHT
	10	PHOTOVOLTAIC MODULE
	11	PLATE-SHAPED MEMBER
30	12	PHOTOVOLTAIC CELL
	13	TRANSPARENT PLATE
	14	INTERLAYER FILM
	15	TRANSPARENT PLATE
	16	DUMMY CELL

21, 22 BUS BAR WIRE

23 JUNCTION BOX

31, 32, 33, 34 WIRE

CLAIMS

[Claim 1]

A photovoltaic module installed on an interior side of a glass
5 window of a building, wherein

an eave is provided at a position of an upper outer part of the
glass window of the building, and

the photovoltaic module is installed so as to satisfy

$$H1-(H2+h) \geq (L+t+d) \cdot \tan\theta \cdots (1),$$

10 where L denotes a horizontal distance from an outer surface of
the glass window to an outer end of the eave, H1 denotes a vertical
distance from a lower end of the eave to a lower end of the glass
window, t denotes a thickness of the glass window, H2 denotes a height
of the photovoltaic module, d denotes a surface spacing between the
15 glass window and the photovoltaic module, h denotes a vertical
distance from the lower end of the glass window to a lower end of the
photovoltaic module, and θ denotes a solar altitude at the place where
the building is built.

[Claim 2]

20 The photovoltaic module according to claim 1, wherein the θ is a
solar altitude at solar noon on the winter solstice at the place where
the building is built.

[Claim 3]

25 The photovoltaic module according to claim 1, wherein the θ is a
solar altitude at solar noon on the summer solstice at the place where
the building is built.

[Claim 4]

The photovoltaic module according to claim 1, wherein the θ is
an annual average solar altitude at solar noon at the place where the
30 building is built.

[Claim 5]

The photovoltaic module according to claim 1, wherein the θ is a
solar altitude at solar noon on the winter solstice or higher but equal
to or lower than a solar altitude at solar noon on the summer solstice.

[Claim 6]

The photovoltaic module according to any one of claims 1 to 5, wherein an average solar absorption rate of the photovoltaic module is 30% or more but 90% or less.

5 [Claim 7]

The photovoltaic module according to any one of claims 1 to 5, wherein a surface spacing d between the glass window and the photovoltaic module satisfies $d \geq 0.5$ mm.

[Claim 8]

10 The photovoltaic module according to any one of claims 1 to 5, wherein when a vertical distance to a lower end of the photovoltaic module based on a lower end of a transmission region of the glass window is denoted by h_2 , $h_2 \geq 20$ mm is satisfied.

[Claim 9]

15 The photovoltaic module according to any one of claims 1 to 5, wherein

the photovoltaic module includes a plurality of photovoltaic cells disposed in a transparent plate-shaped member,

20 the plurality of photovoltaic cells are disposed in an array shape on a principal surface of the plate-shaped member in a horizontal direction and a vertical direction, and

the plurality of photovoltaic cells disposed in the horizontal direction are connected to one another using a wire.

[Claim 10]

25 The photovoltaic module according to claim 9, wherein

the plurality of photovoltaic cells are divided into a plurality of groups, a plurality of photovoltaic cells including a plurality of photovoltaic cells disposed in a horizontal direction and a plurality of photovoltaic cells disposed in a vertical direction forming a unit
30 group,

the plurality of photovoltaic cells included in each of the groups are connected in series with one another using a horizontal wire that connects together the plurality of photovoltaic cells disposed in the horizontal direction and a vertical wire that connects together two

photovoltaic cells adjacent to each other at an end of the horizontal direction, and

a negative side and a positive side of each of the groups are connected in parallel to each other by two bus bars extending in the vertical direction at both ends of the photovoltaic modules in the horizontal direction.

[Claim 11]

The photovoltaic module according to any one of claims 1 to 5, wherein

when a refractive index of air is 1 and a refractive index of the glass window is denoted by n_2 , an amount of deviation ΔH of a solar light which is due to a difference between the refractive index of the air and the refractive index n_2 of the glass window is expressed by $\Delta H = t \cdot \tan \theta - t \cdot \tan \theta_2$, and H_2 in the Expression (1) is calculated as

$H_2 + \Delta H$,

where θ_2 denotes an angle of refraction, and $\theta_2 = \text{Arcsin}(\sin \theta / n_2)$ is satisfied.

[Claim 12]

The photovoltaic module according to any one of claims 1 to 5, wherein the glass window is a multi-layered glass, and when a thickness of a glass plate on an outer side is denoted by t_1 , a thickness of a glass plate on an inner side is denoted by t_2 , a refractive index of air is 1, and a refractive index of the glass plates on the outer side and the inner side is denoted by n_2 , an amount of deviation ΔH of a solar light which is due to a difference between the refractive index of the air and the refractive index n_2 of the glass plate on the outer side and a difference between the refractive index of air and the refractive index n_2 of the glass plate on the inner side is expressed by

$\Delta H = t_1 \cdot (\tan \theta - \tan \theta_2) + t_2 \cdot (\tan \theta - \tan \theta_2)$, and H_2 in the Expression (1) is

calculated as $H_2 + \Delta H$,

where θ_2 denotes an angle of refraction, and $\theta_2 = \text{Arcsin}(\sin \theta / n_2)$ is satisfied.

[Claim 13]

The photovoltaic module according to any one of claims 1 to 5,

wherein

the photovoltaic module includes a plurality of photovoltaic cells disposed in a transparent plate-shaped member, and

5 the photovoltaic module has a configuration in which a transparent first plate-shaped member, an interlayer film, and a transparent second plate-shaped member are laminated, and the plurality of photovoltaic cells are sealed inside the interlayer film.

[Claim 14]

10 A method of installing a photovoltaic module for installing the photovoltaic module on an interior side of a glass window of a building, wherein

an eave is provided at a position of an upper outer part of the glass window of the building, and

15 the photovoltaic module is installed so as to satisfy $H1-(H2+h) \geq (L+t+d) \cdot \tan\theta$,

20 where L denotes a horizontal distance from an outer surface of the glass window to an outer end of the eave, H1 denotes a vertical distance from a lower end of the eave to a lower end of the glass window, t denotes a thickness of the glass window, H2 denotes a height of the photovoltaic module, d denotes a surface spacing between the glass window and the photovoltaic module, h denotes a vertical distance from the lower end of the glass window to a lower end of the photovoltaic module, and θ denotes a solar altitude at the place where the building is built.