(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 November 2009 (19.11.2009)

PCT

(10) International Publication Number
WO 2009/138868 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/IB2009/005603

(22) International Filing Date: 14 May 2009 (14.05.2009)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
08425337.6 14 May 2008 (14.05.2008) EP

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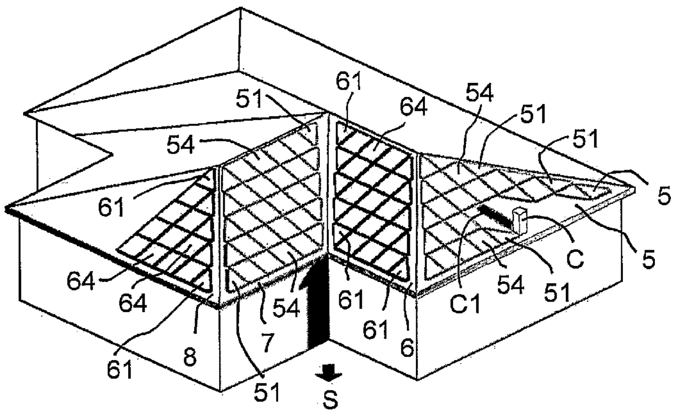
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: MODULAR PHOTOVOLTAIC PANEL SYSTEM

Fig. 21



(57) **Abstract**: System of photovoltaic panels with rectangular (4) and triangular (1) bases combination with each other to form the surface for capturing solar radiation, comprising rectangular and triangular panels, with a number of cells (2) in the triangular panel near the hypotenuse (3) that is equal to the number of cells near each side (L) and rectangular panels with a number of cells on the shorter side (RC) equal to the number of cells present on the side with the triangular panels and a number of cells on the longer side (RL) that is equal to the number of cells present on the shorter side plus one characterised by the fact that the sides of the triangle are equal, that is, the triangular panel has a right-angled triangular shape, and the vertexes of each side and the hypotenuse are cut with short sides (M), which are also equal to each other, near the cell (2) on the end of the row and with a right-angled direction with respect to the side (L); the photovoltaic cells in the rectangular and triangular panels, used for the same system, have the same electrical efficiency characteristics as each other and at least in the production batch and assembly in the system itself, in order to have a no-load voltage, short circuit current (Istc) and a maximum load current (Imax) that is equal for all the cells.

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MODULAR PHOTOVOLTAIC PANEL SYSTEM

Technical field

The present invention relates to a system for manufacturing photovoltaic panels and the special modular panels used in its production and composition. That is, the system uses a new photovoltaic panel conformation, which can be combined in all possible insolation situations that may be obtained over the course of the solar year, in order to make better use of the surfaces available for their application, that is, south facing surfaces on the roofs of buildings, with the aim of maximising the effect of light capture and system yield, also in the presence of obstacles to the said insolation.

Prior art

The prior art already includes photovoltaic panels with cells arranged in rows and columns in order to cover the available surface of the panel itself. The panels are composed with the arrangement of the cells, which have an approximately square conformation, with either bevelled or non-bevelled corners, that is, cells in silicon "monocrystal" or "polycrystal", both with sides measuring either 125 or 155 mm. Standard photovoltaic panels are composed of cells connected together in series, in order to use cells arranged in rows or columns and obtain the shorter side and a longer side of the rectangular panel, the shorter measurements being obtained by using cells with sides measuring 125 mm. The prior art also includes triangular or trapezoid-shaped modules with a lower number of cells than the rectangular modules, to be combined on the available surface and advantageously better exposed to sunlight.

Confirmation of this can be found in previous documents, such as the "SHARP- SUNVISTA" leaflet for photovoltaic panels ref. LN3AH01 dated April 2003 (2003-04), which contains illustrations of both rectangular and triangular panels with cells of the "multicrystal" type, where the number of cells in the triangular panels is half that of the rectangular panels; the rectangular ones have 42 cells and the triangular ones have 21. Furthermore, they are designed to have right-hand and left-hand arrangements as the sides of the triangular panels are not equal, even if there are always 6 cells on each side. A considerable practical disadvantage of this organisation of the set arises from the fact that there is a high number of products, and therefore warehouse management codes, due to the presence of at least six basic shapes, two rectangular and four triangular, due to the use of cells with different dimensions. This is then exponentially increased when taking into consideration all the subdivisions in accordance with the specific photoelectric characteristics that each single cell may have, which is heavily dependent on the production batch. Confirmation is provided by the "PHOTOWAT PW1650 Photovoltaic High Efficiency Module" photovoltaic panel leaflet, dated December 2007, in which various power levels are presented for the same panel, depending on the characteristics of the cells used, which even if they have the same surface area, have different yields for power and current resistance, so the quantity of products to be managed in the warehouse is at least six different types for a single type of panel. There are 72 cells in the panel, subdivided into various strings in series with each other, in order to obtain a prearranged output voltage. The panel has a number of cells on the shorter side of the rectangle that is lower by one cell with respect to those on the longer side. The same arrangement is present in the Sharp rectangular modules mentioned above.

Furthermore, the panels with photovoltaic cells are usually arranged on the roofs of buildings so as to obtain the strongest and most constant levels of illumination. Therefore, when the panels are being arranged on the roofs of buildings, they are placed in the most advantageous position and orientation so as to maximise the light captured over the entire year, as during the winter months even just light is sufficient to trigger the photovoltaic generation of free electrons. These are driven by opposite sides of the silicon in the cell, which acts as a barrier. The flow of free electrons in the electric connections between the cells and the inverter generates electrical energy.

Another aim in the arrangement of photovoltaic panels is to take advantage of the available surface with the highest number of panels, in order to maximise the power that can be obtained from the system, even if the building has limited roof dimensions. As a result, it is now common to place the photovoltaic panels on the roofs of buildings by inserting the panels and their supports into the actual roof thickness, by removing the tiles and replacing them with the panels at the same level as the tiles which are left in position at the sides. This method therefore respects the architectural silhouette of the building and means that the panels can be firmly fixed and be at the same height as the roof and tiles and be matched alongside them.

The document JP 2001 073522 included in the prior art describes a roof of a building that was built especially to house the photovoltaic panels and maximise the roof covering. It describes the formula for the sizes and numbers of panels, starting from the roof measurements and the inclination of the slope. In the text, various panel types are described: rectangular ones with 20 to 30 cells and also triangular ones with 10 cells and trapezoidal ones with 20 cells. The plan for constructing the system, which is then created based on this, is characterised by a considerable number of also small panels, so as to completely cover the roof pitches, as a result creating a very high number of electrical connections between the panels, as can be seen in the numerous examples. A high number of connections is extremely advantageous to the duration of the system as the electrical junctions in the wires between the panels are subject to breakage over time due to the variability of oxidation in the contacts with increase in resistance, thus greatly reducing the reliability of the system; given the solely geometric arrangement for installing the system on the roof, the technical problem of connecting the panels to obtain balanced strings and avoiding the occurrence of "mismatching" between strings connected in parallel remains to be solved.

The problem of organising the photovoltaic panels in the best way possible on the roof of a building with any shape is also discussed in the previous document US 6,525,262, which describes the various problems regarding the connection of strings of cells, the various panels in question and the distribution of the cells in the panels so as to minimise the problem of "mismatching" that is typical when connecting strings in parallel: a recirculation current is established between two strings in parallel if the electrical voltage-current characteristics do not correspond; this leads to overloading of the cells above the usable current with a recirculation current that compromises the yield of the system. The document illustrates various examples for the application of connections in parallel between strings and the solution to the complex problem of organising the system of photovoltaic panels with good covering of the available surface and a good yield for the assembled panels. It is resolved by using a group of rectangular panels with sides that have very different measurements, so as to be of equal width, but with different lengths by at least two measures. The text shows examples of coverings, with calculations of percentages obtained, and examples of electrical connections to limit "mismatching" between strings. It also deals with the functioning problems of the system, but this is limited to the connection with the inverter and its activation on reaching the minimum voltage. The document does not solve the problem of limiting and simplifying the electrical connections, given the high number of panels used. Furthermore, it does not deal with the interference of obstacles that may shade even just a single cell in a string, thus obstructing the current flow in the cell making the string in which it is found ineffective, and thus limiting the efficiency of the system, even when by-pass diodes are present.

As is known, all the cells have a typical voltage that is not lower than 0.4 V or higher than 0.7 V, depending on the treatment of the silicon layer and its quality. Typically, in most cases the working voltage is 0.5 V, independently of the size (side measuring 125 mm or 155 mm) of the cell. Other parameters like power, duration and internal resistance do not affect the voltage, as this is an electrochemical effect of the excitation of the silicon layer due to the light photons crossing it, whereas the internal resistance of a panel affects the current that crosses it. For this reason the best system solution is to install identical modules, that is, with cells manufactured in the same batch, so as to guarantee electrical compatibility between the panels and minimise loss due to current crossing in the string of panels/cells. Furthermore, parallel coupling of strings of panels/cells that are not perfectly identical causes "mismatching" due to the different voltage/current yield of the strings.

When positioning the panels, on the roof or within the actual roof thickness, the panels cannot be placed near the ridge of the roof to leave space for placing the tiles, as is common, to maintain the hip slope variation of the roof. With the rectangular panels of the prior art, in this type of assembly, a certain distance must be maintained between the vertexes of the panels nearest the ridge and the said ridge of the roof in question. The panels described in the previous documents were only designed with the geometric coverage of the roof in mind, and therefore the problems involved in the installation of a photovoltaic panel system for the actual roof size are often not resolved. These include the presence of obstacles, such as chimneys, antennas, shading constructions, trees, etc., which tend to shade the panels or a part of them, above all and not only on winter days with limited insolation, thus making the single string in question ineffective or the overall system if made with a single string, if the panels are not provided with by-pass diodes so as to minimise the number of photovoltaic cells affected by the shading as much as possible.

Even if the previous document US 6,525,262 deals with the effect of "mismatching" between strings, the proposed solution does not help, or may even worsen, the guaranteed functioning over time. Indeed the high number of connections between panels is the cause of possible breakage when the system is used over time, which may be up to 30 years. Therefore, the problem of coordinating the parts of the photovoltaic panel system to make its functioning guaranteed and reliable has not been resolved.

Therefore, with the panels of the prior art on the available surface of the roof, the approximately triangular surfaces near the ridge vertexes are covered and thus make the correct positioning of the tiles along the ridge possible.

Therefore, the necessity to achieve the maximum performance that can be obtained with the available roof surface requires the photovoltaic panels to be of opportune shape and size to take advantage of the roof surface in the best possible way. With this aim the triangular-shaped panel with 21 photovoltaic cells arranged in series, which is then combined with rectangular panels with 42 cells made by Sharp, has to be manufactured with a right and left-hand conformation, as the lengths of the sides are different, in order to be coupled with the rectangular panel on just one side.

This prior art is subject to further improvement with regard to the possibility of producing a system of photovoltaic panels that allows the above-mentioned drawbacks to be eliminated, to make better use of the available roof surface and, in particular, combine the panels in order to obtain functioning of the system, which is more constant, reliable over time and more flexible in the arrangement of the various components as well as maximum overall yield of the cells, circuitry and functioning of the inverter.

From what has been described above, it is clear that it is necessary to solve the technical problem of finding a new conformation for the photovoltaic panels that is both triangular and rectangular, so as to make the electrical and dimensional combination of the bases of the panels quicker and easier when covering the roofs of buildings. At the same time, this would enable high voltage levels to be obtained in order to provide optimal supply conditions for the inverter also with one or few strings. Also at the same time, it would provide versatility in assembly to cover the areas of the roof, in order to avoid shading by obstacles on winter days when the incidence of sunlight is at the lowest value. Furthermore, again at the same time, it would enable costs of production and technical conformity to fixed standards (certification) to be minimised, as well as those of warehouse management, where the electrical characteristics among the batches of cells used in the construction of panels are varied, which in theory, but not in practice, are identical, and also the management of warehouse stocks.

Summary of the invention

The invention solves the above-mentioned technical problem, by using a system of photovoltaic panels with rectangular and triangular bases in combination with each other to form the surface for capturing solar radiation, comprising rectangular and triangular panels in which the number of cells near the hypotenuse is equal to the number of cells near each side and rectangular panels with a number of cells on the shorter side equal to the number of cells present on the side with the triangular panels and a number of cells on the longer side equal to the number of cells present on the shorter side, plus one, characterised by the fact that the sides of the triangle are equal, that is, the triangular panel has a right-angled triangular shape, and the vertexes of each side and the hypotenuse are cut with short sides, which are also equal to each other, near the cell on the end of the row and with a right-angled direction with respect to the side (L); the photovoltaic cells in the rectangular and triangular panels, used for the same system, with the same electrical efficiency characteristics as each other and at least in the production batch and assembly in the system itself, in order to have a no-load voltage, short circuit current (Istc) and a maximum load current (Imax) that is equal for all the cells.

In a further embodiment: the triangular panel can be installed on the left or right side of the rectangular panel, without distinction, and the triangular panel in the system is used aligned or slightly staggered with respect to the rectangular panel alongside it.

A specific embodiment of the invention involves the use of photovoltaic cells with sides that measure 125mm; these may be of the type obtained using silicon monocrystal or polycrystal.

Furthermore, in a preferred embodiment: the rectangular panel has eight cells on the shorter side and nine cells on the longer side and the triangular panel has eight cells on each side.

Yet furthermore, in a preferred embodiment: the combination of rectangular and triangular panels is carried out indifferently in the same string for the power supply of the inverter for electrical current transformation from direct current to alternating current.

Furthermore, in a preferred embodiment: the combination of rectangular and triangular panels of the invention has the triangular panels arranged, with regard to laying the panels on a roof in general, in a certain way so as to avoid obstacles to sunlight illumination and avoid shading of the said panels.

Finally, in a further embodiment of the invention: the combination of rectangular and triangular panels has panels arranged, with regard to laying the panels on a roof in general, on at least two strings to avoid constructions that may shade the said panels from sunlight illumination, even for just a few days in the winter months, or to enable precise subdivision into identical numbers of panels in the strings.

Brief description of the drawings

An embodiment of the invention is illustrated, purely in the form of examples, in the eleven drawings enclosed, where Figure 1 is a schematic plan view of a triangular-shaped photovoltaic panel with 36 cells, in accordance with the invention; Figure 2 is a schematic plan view of a rectangular-shaped photovoltaic panel, with 72 cells, which can be combined when assembling systems with the photovoltaic panel in Figure 1; Figure 3 is a schematic plan view of the arrangement of photovoltaic panels in Figures 1 and 2, in accordance with the invention; Figure 4 is a schematic view similar to Figure 3 in which the rectangular photovoltaic panels have been rotated by 90 degrees, so as to make the best use of the actual roof surface on which the system has been installed; Figures 5 and 6 show a schematic view of a construction that may shade the panels alongside a panel system, in the two views from right and left with respect to the southerly direction S shown by the arrow: the shade is calculated for the early morning in the month of December when there is the minimum level of insolation, in accordance with the invention; Figures 7 and 8 show the arrangement of the panels, in accordance with the invention, to avoid the shading construction shown here from 8.00am to 4.00pm on a day in December with minimum insolation levels; Figures 9 to 20 show schematic views of the arrangement of the panel system, in accordance with the invention, with a chimney shading the system on the 15th December, shown at various consecutive times, from 9.15am to 3.00pm: the arrangement of the panels, in accordance with the invention, avoids the shading of even the smallest part of a panel, so as to enable the use of a single string and make the system efficient under all conditions of insolation; Figures 21 to 25 show schematic views of a panel system arrangement; in accordance with the invention, with a chimney shading the system on several adjoining slopes and oriented in a direction that is not southerly: the Figures highlight the movement of shadows with which the system, in accordance with the invention, maintains maximum efficiency and is extremely superior to the panels and methods known in the prior art, also in the conditions of insolation shown at 8.30am in the month of February, Figure 21, at 8.00am in the month of April, Figure 22, from 11.00am to 2.30pm in the month of December, Figures 23-25; Figure 26 is a perspective schematic view of a small system comprising four rectangular panels 4 and four triangular panels 1, with the arrangement shown in Figure 4; Figure 27 is the electrical diagram of the connection of the inverter to the electrical line to enable the electrical energy produced to be transferred; Figures 28 and 29 are schematic views that are similar to the previous two, for a system with two strings composed of nine rectangular panels 4 and one triangular panel 1, for each; Figures 30, 31 and 32 are schematic views that are similar to the previous two for a large system with 6 strings composed of seventeen rectangular panels 4 and one triangular panel 1, for each, where Figure 32 is the enlargement of the XXXII area of Figure 31.

Detailed description of a preferred embodiment

In the Figures, label 1, Figure 1 shows the triangular panel in accordance with the present invention, which has two sides L of identical length, as they comprise eight photovoltaic cells 2, laid alongside each other, of the monocrystal square type with bevelled vertexes and sides measuring 125 mm. The total number of cells is thirty-six as the cells of the hypotenuse 3 are all included in the group of cells used for the triangular panel 1, the sides of the panel measure 1070 mm (+/-5 mm), the shorter sides M, positioned to cut the vertexes, measure 155 mm (+/-5 mm).

Figure 2 also shows a panel 4 with photovoltaic cells 2, alongside each other, of the monocrystal square type with bevelled vertexes and sides measuring 125 mm, arranged to form a rectangle with sides of similar lengths. Indeed, the side of the panel RC, which is shorter, is located on the side where there are eight cells 2, while on the side next to this, which is a bit longer RL, there are nine cells 2. The cells are identical to those used in the triangular panel 1. The total number of cells is seventy-two and the sides of the panel measured 1070 mm (+/-5 mm) for the shorter one RC, and 1200 mm (+/-5 mm) for the longer one RL.

Furthermore, Figure 3 shows the arrangement of the photovoltaic panels in plan view of a roof pitch F of a roof on which the system has been installed. In Figure 4 the rectangular photovoltaic panels 4 have been rotated by 90 degrees, with respect to the arrangement in Figure 3, so that the surface covered by the roof pitch F is identical, whereas the conformation of the system has a distance D for matching with the ridge P of the most constant roof pitch. The possibility of combining the rectangular photovoltaic panels 4, whether they are rotated or not rotated, enables the actual conformation of the surface covered to be adapted to the variable, among different roofs, of the convergence, which may be more or less accentuated, of the ridge P lines.

The triangular panel 1, due to its shape with vertexes cut in the shorter sides M, enables it to be oriented in the most convenient way to cover the surface that can be used, also taking into consideration the obstacles between the sunlight and the panel. The combination of the rectangular and triangular panels in the arrangements shown in Figures 1 and 2 enables the number of articles held in the warehouse to be reduced, as the panels must be subdivided depending on the electrical characteristics of the cells used, so panels with different resistance characteristics cannot be used together in the same string, or adjacent strings. Panels that are structurally the same but with different electrical characteristics must be used separately in different systems; for this reason the management of panels between manufacture and installation must be carried out in such a way to avoid large stocks of panels being created, as they cannot be used together with others, in order to reduce the level of capital wasted on the cost of panels that will no longer be used or are difficult to use in other systems.

The application of the photovoltaic panel system, as mentioned above, is versatile and can be adapted to the actual conformation of the roof on which it is to be installed. In the examples of arrangements in Figures 5-25, there are adaptations of the panel system that may be made in the presence of shading obstacles which, as mentioned previously, would make the system or one of its strings ineffective, even if only a small part of a single panel was shaded; in the following Figures the southerly direction is indicated by the letter S and the shadows are calculated for the latitude of Italy.

In Figures 5 and 6 the arrangement of the rectangular panels 4 and the triangular panels 1 enables the shading OS of the adjoining wall structure MC on the roof pitch F to be avoided. Similarly, in Figures 7 and 8, where there is a gable roof AB or similar construction that juts out from the roof pitch F of the roof, which is already advantageously oriented towards the south, the shading OB of the gable roof can be avoided by the panels by using a combination of rectangular panels 4 and triangular panels 1; the shading shown is the maximum possible, for the levels given for the month of December; during the other months the sunlight incidence is always greater. However, it is not useful to take advantage of the shaded surface OS during the months in which the shadow is shorter, as the panels that may be used would bring about a cost that cannot be amortized and would make the entire system ineffective during the winter months if even a single part of a panel was covered by a shadow, thus reducing the efficiency of the system to low or nonexistent levels. The arrangement of the rectangular and triangular panels of the invention, which can be combined, guarantees the best cover also in the presence of the inevitable shadowing shown.

In Figures 9-20, the presence of a chimney CM in a corner of the roof with roof pitch F on which the system has been installed is highlighted by the movement of the shadows of the chimney on the days with minimum sunlight in December from morning to evening. The shadow of the chimney OC1-OC12, thanks to the particular arrangement of the rectangular panels 4 and triangular panels 1, does not cover any parts of the panels, even though in the minimum sunlight incidence conditions during the winter months, the effectiveness of sunlight capture and use of the cells is always at a maximum. The Figures, having been drawn with the sunlight position from morning to evening on the

15^{th} December, highlight how, with thirteen rectangular panels 4 and two triangular panels 1, it is possible, with the photovoltaic cell panel system of the invention, to create a system with a single string that can provide a trigger voltage which is always greater than the inverter under all working conditions, thus guaranteeing maximum efficiency even with a single string of panels. In fact, inverters notoriously require a voltage that is not lower than 200 V to start the transformation of energy from direct current to alternating current; furthermore it is known that inverters reach maximum performance and high yield if powered with a voltage of at least 400-500 V. In this case, the fourteen panels (13+1/2+1/2) can supply a no-load working voltage of approx. 500 V to the inverter, thus providing it with the best working conditions.

Figures 21 to 25 show a system with rectangular 4 and triangular 1 photovoltaic panels on the roof of a building with several sloping roof pitches 5, 6, 7 and 8, some of which face south-east, 5 and 7, and some south-west, 6 and 8; a chimney C is present on the roof pitch 5 facing south-east, so it is necessary to limit the photovoltaic panels on the main roof pitch 5, to avoid shading from the said chimney, shadows C1-C5, and as a result, there is a reduction in the efficiency of the system. In Figure 21, the shading, shadow C1, is calculated for the month of February, in the winter, in the morning: the triangular 51 and rectangular 54 panels present on roof pitches 5 and 7 are illuminated and can generate the voltage necessary for triggering the inverter (not shown), while the triangular 61 and rectangular 64 panels on roof pitches 6 and 8 are not illuminated and must be designed on a different string in order to enable them to be excluded and avoid “mismatching” between the strings; the system, even if at reduced power, can work with maximum efficiency by avoiding unwanted shade and making sure to use two separate inverters or one inverter of the type with the connection of two separate string inputs, that is, “multi-string-control”. In Figure 22, the shading, shadow C2, is calculated for the month of April, in spring, in the morning: the panels on roof pitches 5 and 7 are illuminated, similarly to the previous Figure, while the panels on roof pitches 6 and 8 are not illuminated; the functioning of the system is similar to that in the previous Figure with just a greater incidence of sunlight on the horizon. In Figures 23-24 the same system as in the previous Figures is subject to the midday light, from 11.00am to 1.00pm, even if in winter, in December: insolation is at a maximum for all the panels on the roof pitches in question: the system, even in the presence of a low sunlight incidence, shadows C3 and C4 from the chimney C, can operate at maximum efficiency, owing to the mixed arrangement of rectangular 54 and triangular 51 panels, on the roof pitch 5, to follow the progress of the chimney C, thus avoiding problems of inefficiency of the string of panels if shaded. In the last Figure 25, in relation to this system of photovoltaic panels, the illumination is calculated after half a day, at 2.30pm, in winter, in December; also with reduced insolation for all the panels on the roof pitches: the system, with low incidence light, shadow C5 from the chimney C, can operate at maximum efficiency. In Figures 26 to 28 in the two examples of small systems, one of 1.08 kW and a larger one of 3.42 kW, E1 indicates the electrical diagram of a triangular panel 1 and E4 indicates the electrical diagram of a rectangular panel 4. The small system has a single string St, whereas the larger one is subdivided into two strings S1 and S2. The strings are connected to a circuit-breaker relay in direct current RB before the inverter and below it another circuit-breaker relay in alternating current RA connects the system to the electricity network NE by means of the meter MS. The system shown in Figure 26, where the panels are arranged to cover the roof pitch F of the roof, makes the best use of the geometrical versatility of the triangular panels in the invention; while in the system shown in Figure 28 the use of triangular panels 1 serves to avoid the shadow CO and the presence of the said chimney C.

Finally, Figures 30, 31 and 32 show a system for an industrial warehouse, which would normally create problems in terms of subdividing the rectangular panels 4 into strings, which must be of a sufficient number to cover the surface of the roof pitch F; in the example there are seventeen rectangular panels and one triangular one for each of the six strings. The system shown enables the dimensions of the strings to be determined with double the number of possible combinations with respect to the use of single modules; in this case the triangular modules 1 are placed opposite each other so as to be complementary and form a rectangle with measurements that are adapted to the rectangular modules, and also from the “electrical” point of view, where the triangles represent the separation terminals between two different strings. With the modular panels of this invention, it is possible to use a single inverter, also in large systems, and thus avoid subdividing them for more than one inverter, so as to keep costs low.

The advantages achieved with this invention are: the system of photovoltaic panels comprising at least one triangular panel 1 enables a combination of the panels in a simple way and in series with the rectangular panels 4, for the electrical connection of panels with each other, so as to permit the same type of electrical connection. Yet furthermore, the conformation of the triangular panel is only slightly bigger than the exact conformation of half of the surface of the corresponding rectangular panel: in fact, the arrangement of the cells with 8 rows and 9 columns, or vice-versa, only slightly changes the orientation and positioning of the roof surface occupied; therefore, given the possibility of carrying out the electrical connections appropriately, the rectangular panel can be rotated or not rotated with respect to the side L of a triangular panel alongside it, so as to only slightly change the measurements of the surface covered on the roof and better adapt the position of the vertexes of the panels near the ridge of a roof between the adjoining hips. The triangular panel with cut vertexes is equilateral, with equal sides L, and has shorter sides M, which are also equal, to limit overhang near the ridge line of the roof pitch. Furthermore, the combination of the photovoltaic panels enables high voltage levels to be obtained, to provide optimal power supply conditions for the inverter, even with one or few strings; the limited number of panels provides for guaranteed and reliable functioning over time, as the electrical junctions, which may be a source of future breakages, are reduced in number. Yet furthermore, the versatility in assembly to cover the areas of the roof allows for the avoidance of shading by obstacles also on winter days when the sunlight incidence is at its minimum value. The last but not least advantage is the economic one, which is evident, in that the set of rectangular and triangular panels described enables the costs of production and technical conformity to fixed standards (certification) to be minimised, as well as those of warehouse management, where the electrical characteristics among the batches of cells used in the construction of panels are varied, which in theory, but not in practice, are identical, and also the management of warehouse stocks, that is, panels that have not been installed due to excess production with regard to the number required for a system.

Furthermore, in the case of systems with large dimensions with south-facing roof pitch F surfaces of industrial warehouses, Figure 31, the panel system, in accordance with the invention, enables the use of all the available space on the covering; at the same time it enables all the photovoltaic panels to be divided into strings that are identical to each other and strings with the highest working voltage possible to be created, without exceeding the no-load voltage limit values (typically 20% - 25% higher than the nominal voltage) of the inverter; for large systems, where inverters with voltages on the direct current side to the order of 800 VDC are used, it is possible to use modules with half the power, like the triangular modules 1, limiting the management of the energy produced to a single inverter, thus making the system much less expensive.

To summarise, with the system of modular photovoltaic panels described above, by having just two modular panels with photovoltaic cells which in the system have two single orthogonal side dimensions, without being obliged to lay them in a particular way (e.g. right-left), it is possible to perform calculations for the greatest cover, for the roof pitches of the roofs in question and for maximum efficiency and electrical yield of the system, also over time, in a quick and simple way, at the same time obtaining the lowest purchase, installation, functioning and maintenance costs, among the thousands of combinations possible for the modular panels and types of inverter with various formats and electrical yield present on the market.

In practical implementation, the materials, dimensions and realisation details may be different from those indicated, but technically equivalent to them, all of which, however, are included within the scope of protection of the present invention as defined by the following claims.

Claims

1. System of photovoltaic panels with rectangular (4) and triangular (1) bases combination with each other to form the surface for capturing solar radiation, comprising rectangular and triangular panels, with a number of cells (2) in the triangular panel near the hypotenuse (3) that is equal to the number of cells near each side (L) and rectangular panels with a number of cells on the shorter side (RC) equal to the number of cells present on the side with the triangular panels and a number of cells on the longer side (RL) that is equal to the number of cells present on the shorter side plus one characterised by the fact that the sides of the triangle are equal, that is, the triangular panel has a right-angled triangular shape, and the vertexes of each side and the hypotenuse are cut with short sides (M), which are also equal to each other, near the cell (2) on the end of the row and with a right-angled direction with respect to the side (L); the photovoltaic cells in the rectangular and triangular panels, used for the same system, have the same electrical efficiency characteristics as each other and at least in the production batch and assembly in the system itself, in order to have a no-load voltage, short circuit current (Istc) and a maximum load current (Imax) that is equal for all the cells.

2. System of photovoltaic panels, in accordance with claim 1, characterised by the fact that it has a triangular panel (1) which can be installed on the left or right side of the rectangular panel (4), without distinction.

3. System of photovoltaic panels, in accordance with claim 1, characterised by the fact that the triangular panel (1) in the system is used aligned or slightly staggered with respect to the rectangular panel (4) alongside it.

4. System of photovoltaic panels, in accordance with claim 1, characterised by the fact that it involves the use of photovoltaic cells (2) with sides that measure 125 mm.

5. System of photovoltaic panels, in accordance with any of claims 1, 2, 3 or 4, characterised by the fact that it involves the use of photovoltaic cells (2) of

the type obtained using silicon monocrystal.

6. System of photovoltaic panels, in accordance with any of claims 1, 2, 3 or 4, characterised by the fact that it involves the use of photovoltaic cells (2) del of the type obtained using silicon polycrystal.

7. System of photovoltaic panels, in accordance with any of the previous claims, characterised by the fact that it has a rectangular panel with eight cells (2) on the shorter side (RC) and nine cells on the longer side (RL) and a triangular panel with eight cells (2) on each side (L).

8. System of photovoltaic panels, in accordance with any of the previous claims, characterised by the fact that the combination of rectangular (4) and triangular (1) panels is carried out indifferently in the same string for the power supply of the inverter (I), for electrical current transformation from direct current to alternating current.

9. System of photovoltaic panels, in accordance with any of the previous claims, characterised by the fact that the combination of rectangular (4, 54, 64) and triangular (1, 51, 61) panels has panels arranged, with regard to laying the panels on a roof in general, on at least two strings to avoid obstacles (AB, MC, CM, C) to sunlight illumination and avoid shading (OS, OB, OCx, Cx, CO) by them.

10. System of photovoltaic panels, in accordance with any of claims 1 to 8, characterised by the fact that the combination of rectangular (4, 54, 64) and triangular (1, 51, 61) panels has panels arranged, with regard to laying the panels on a roof in general, on at least two strings (S1, S2, Sx) to avoid constructions that may shade the said panels from sunlight illumination, even for just a few days in the winter months, or to enable precise subdivision into identical numbers of panels in the strings.

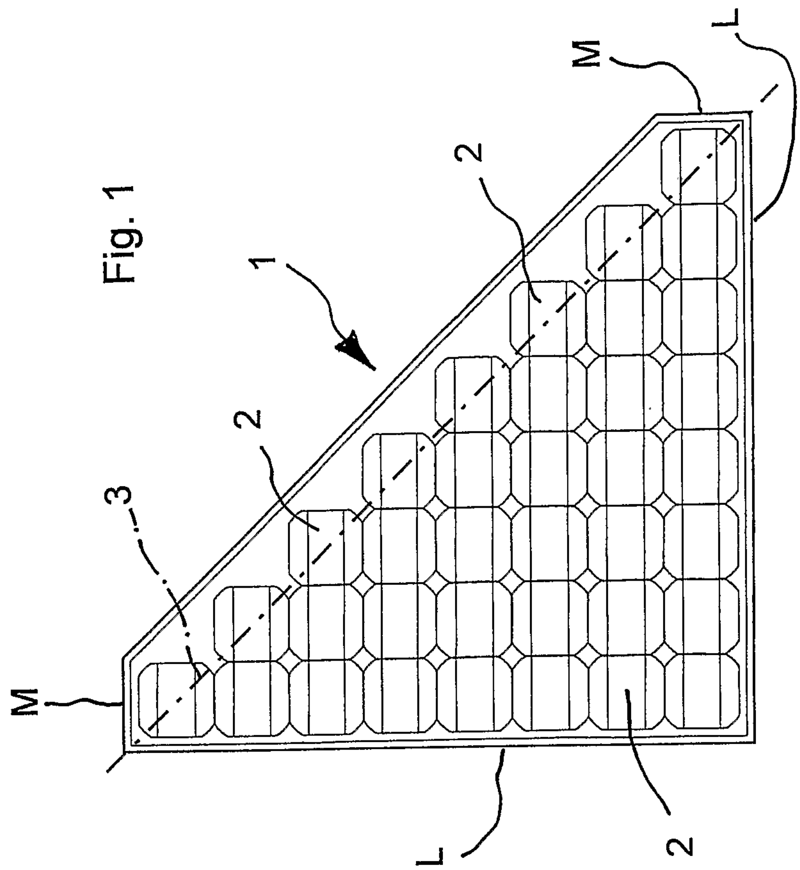


Fig. 1

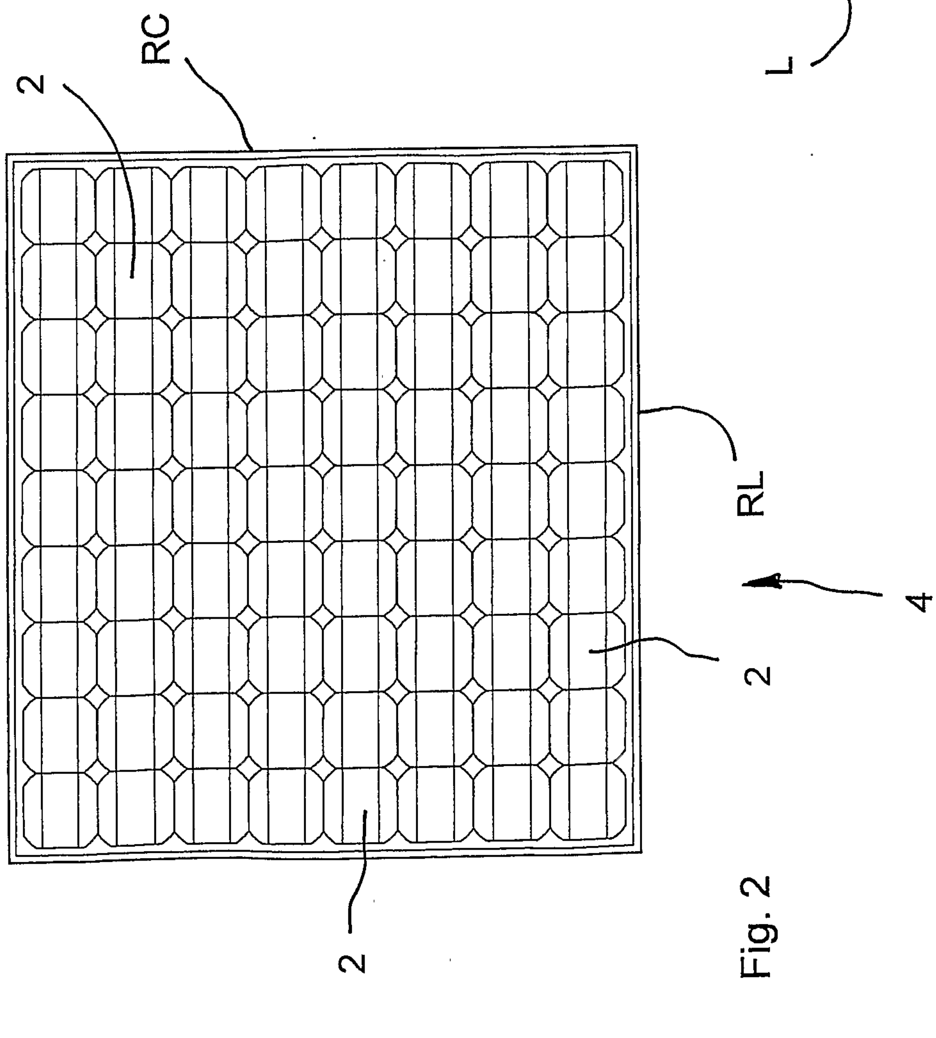


Fig. 2

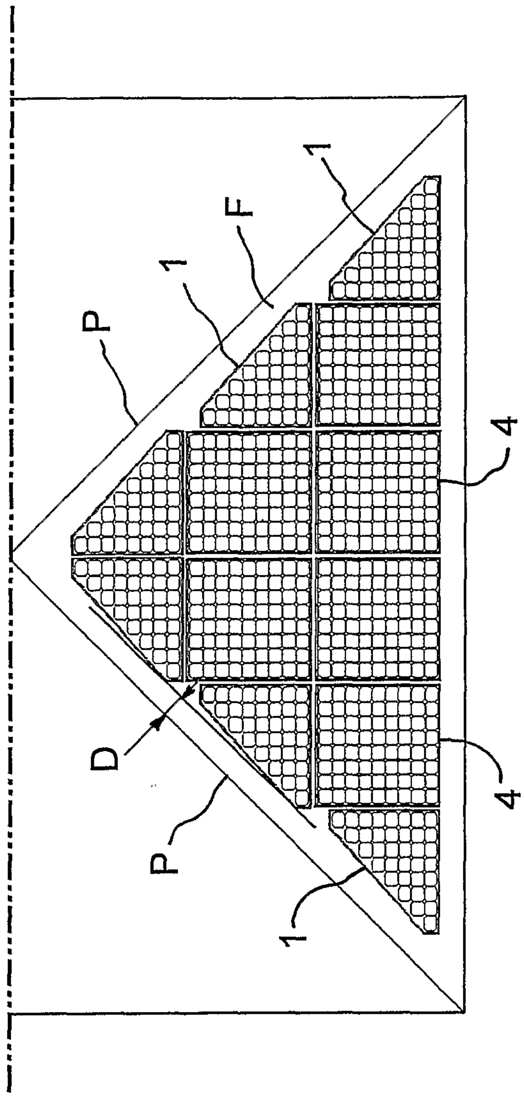


Fig. 4

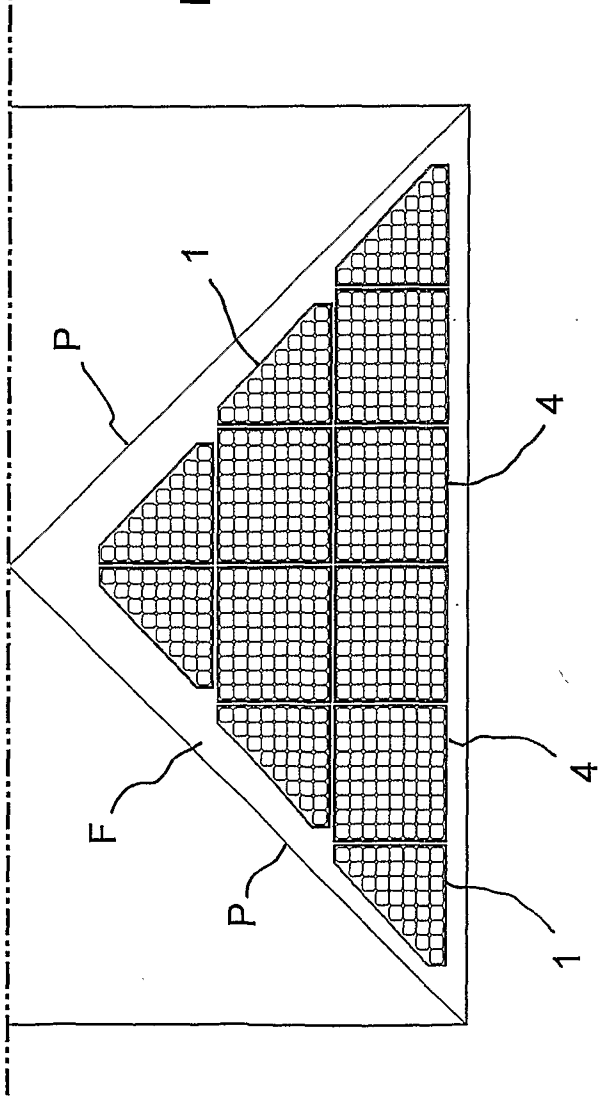


Fig. 3

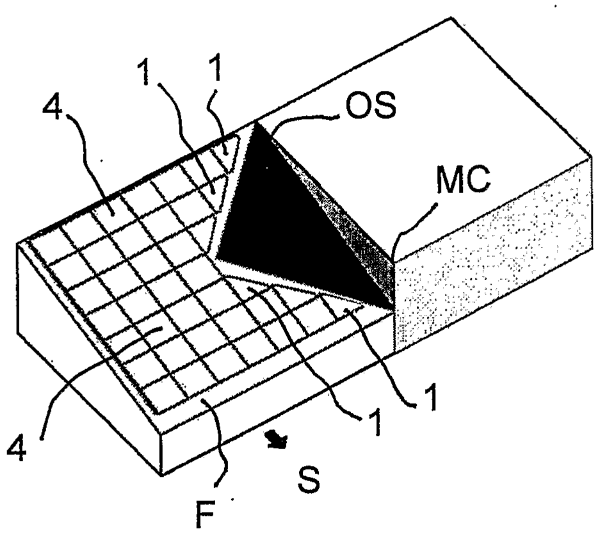


Fig. 5

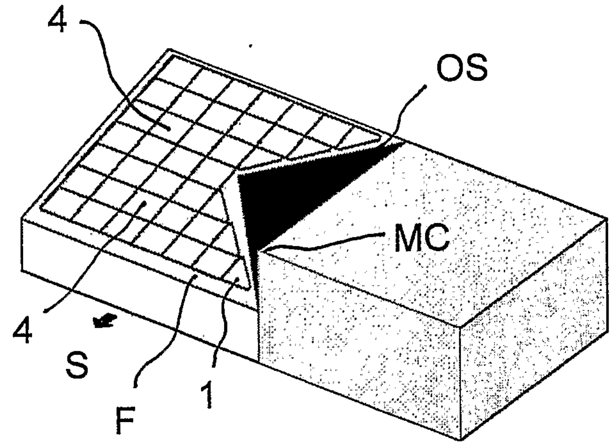


Fig. 6

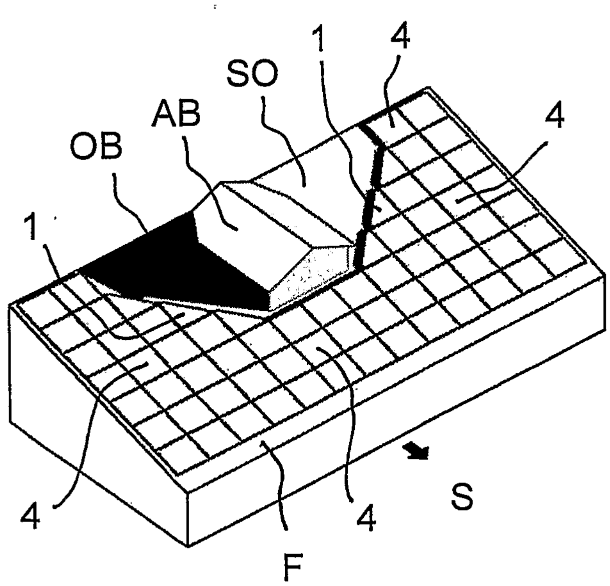


Fig. 7

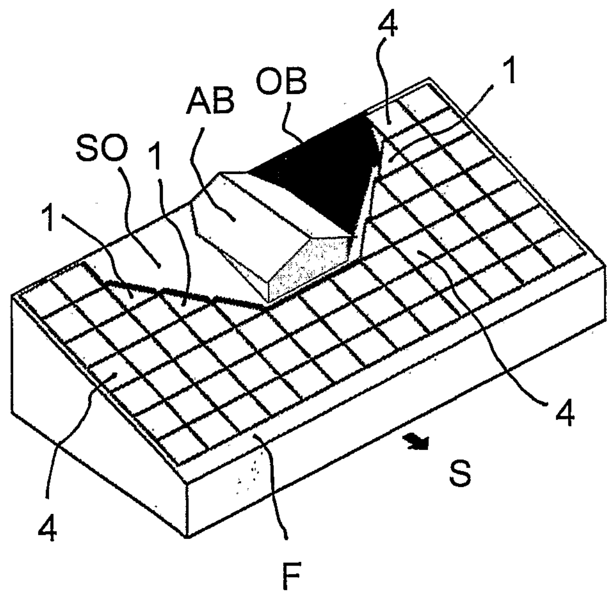


Fig. 8

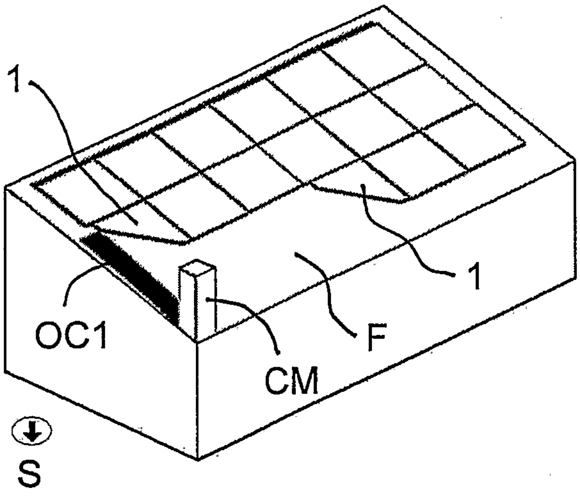


Fig. 9

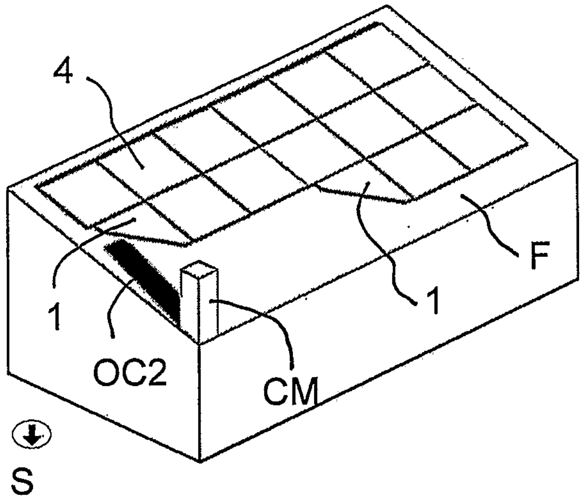


Fig. 10

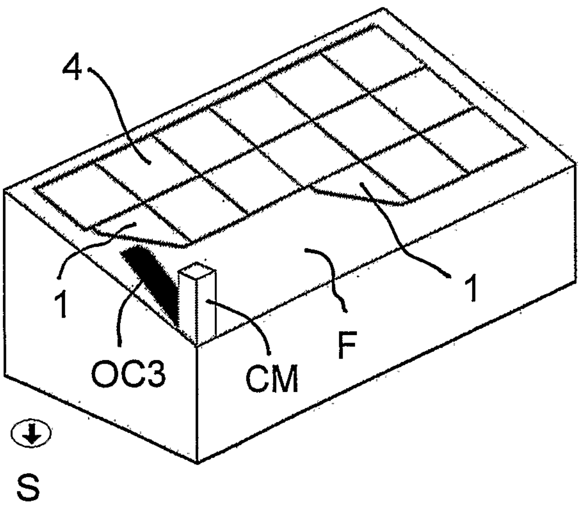


Fig. 11

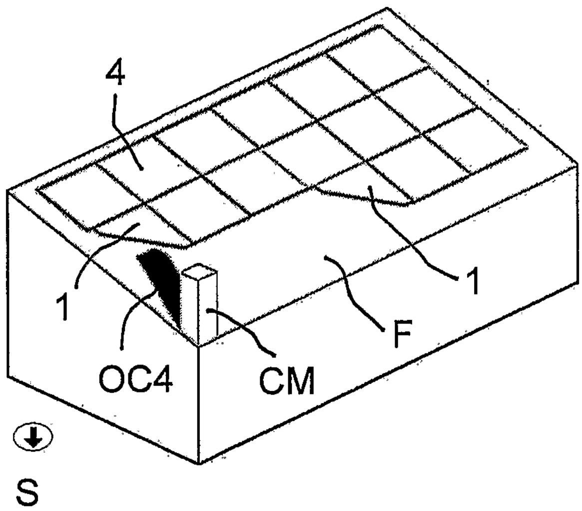


Fig. 12

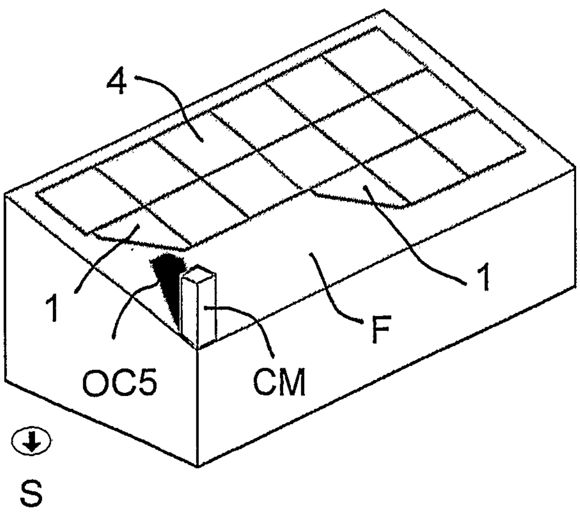


Fig. 13

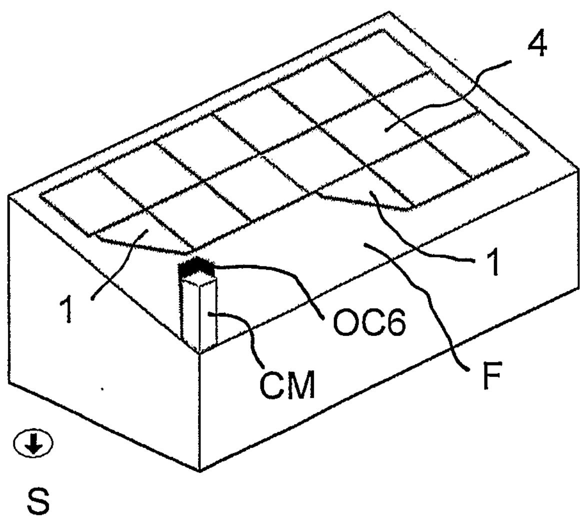


Fig. 14

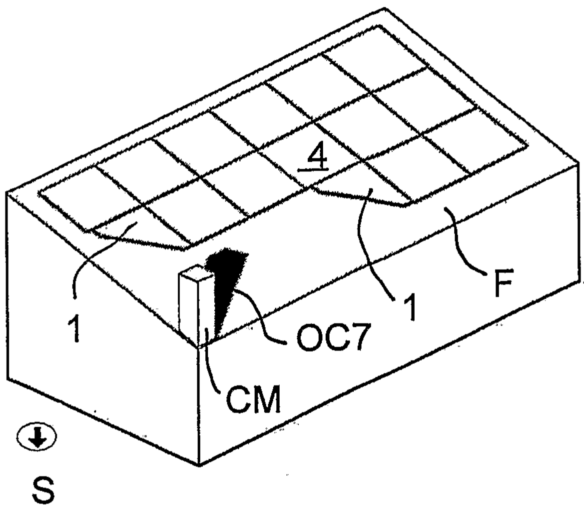


Fig. 15

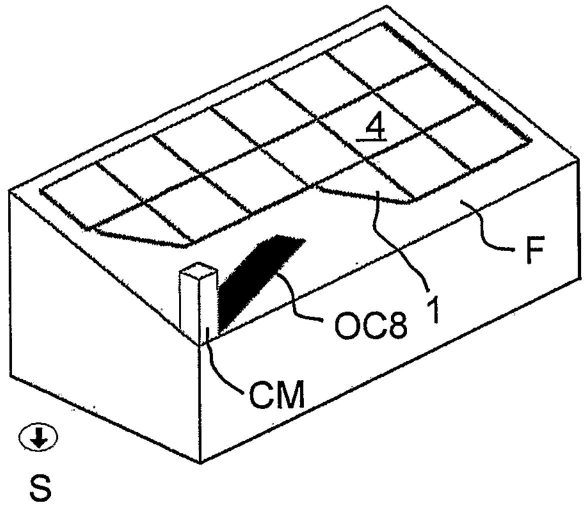


Fig. 16

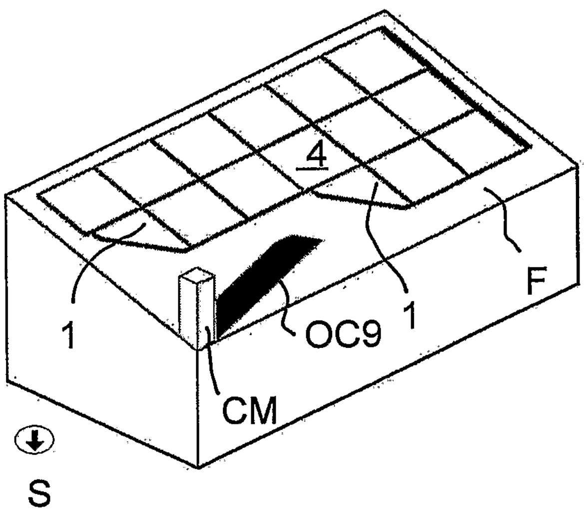


Fig. 17

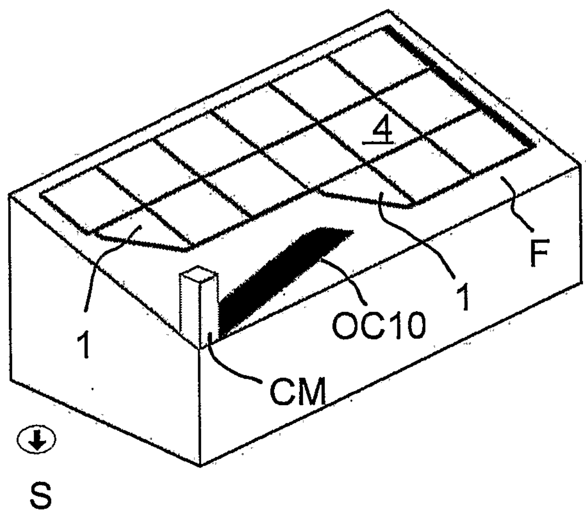


Fig. 18

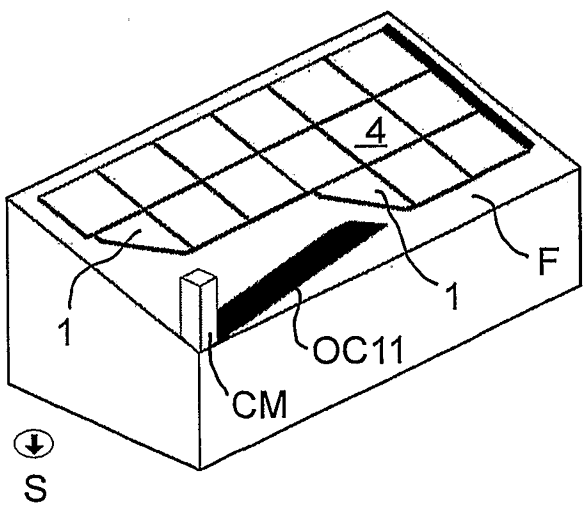


Fig. 19

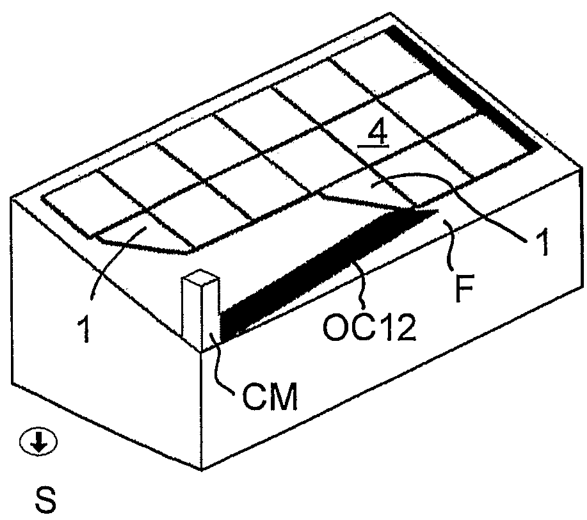
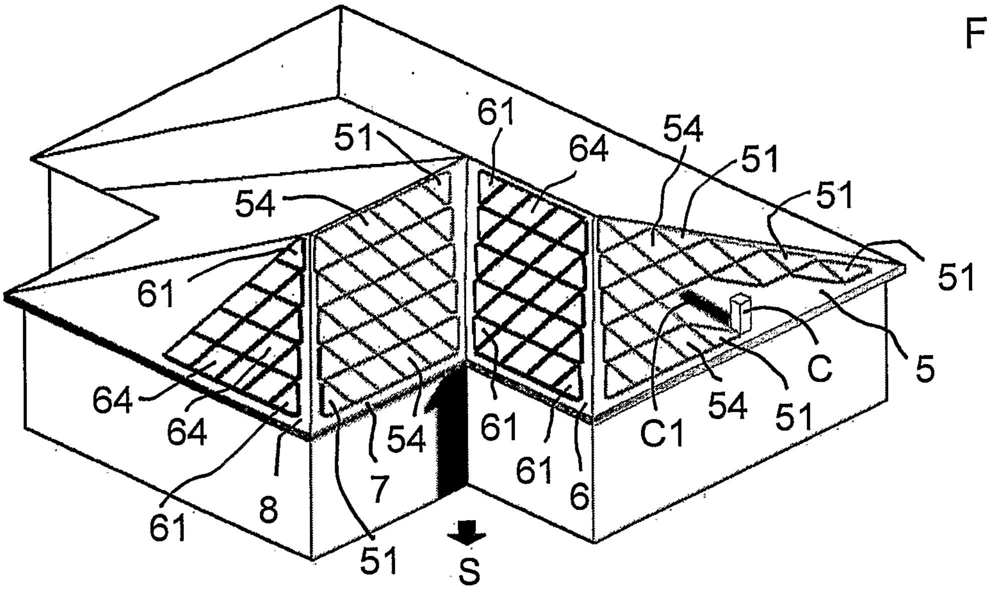


Fig. 20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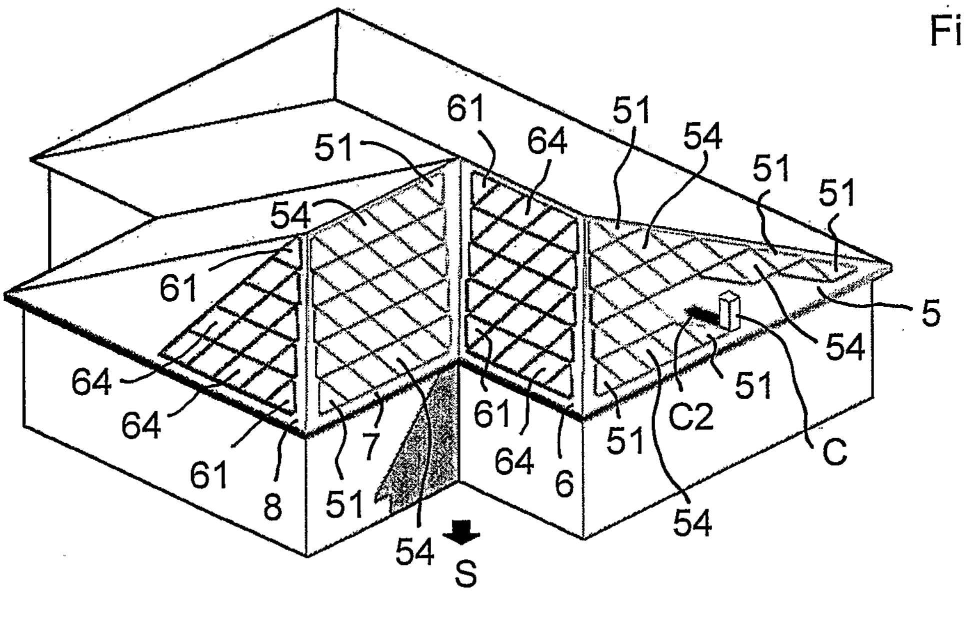
61
64
54
51
51
54
61
51
5
C
64
C1
54
51
61
64
61
54
61
7
61
6
8
61
51
S

Fig. 21


61
51
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51
54
51
54
51
61
5
54
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64
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C2
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7
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51
54
54
S

Fig. 22

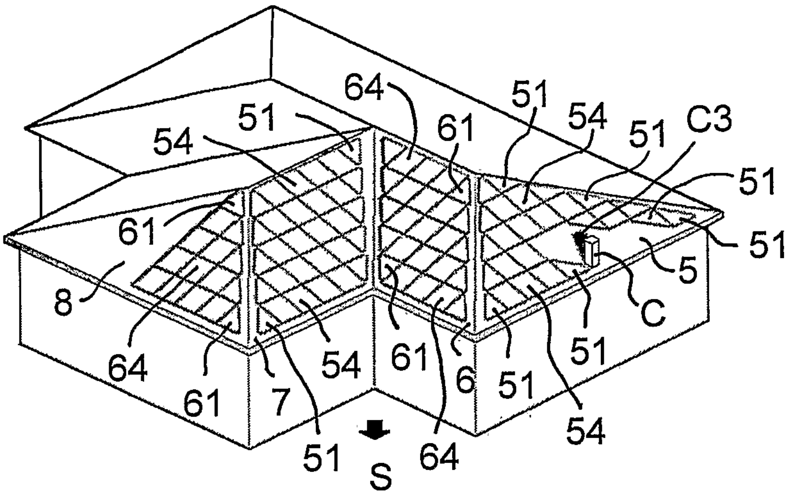


Fig. 23

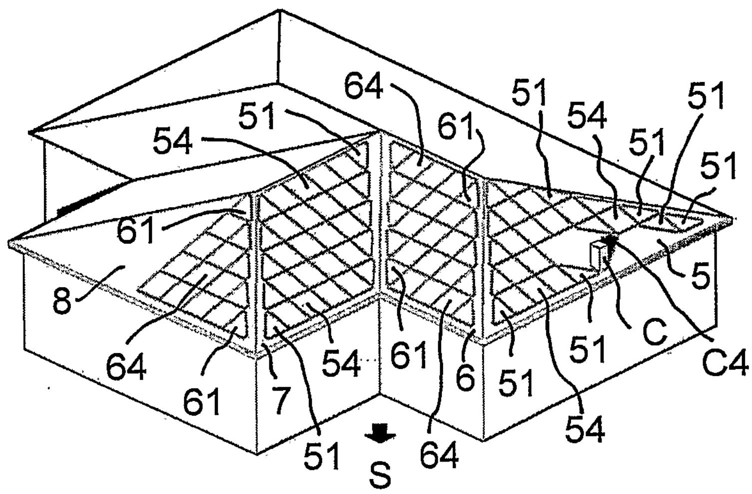


Fig. 24

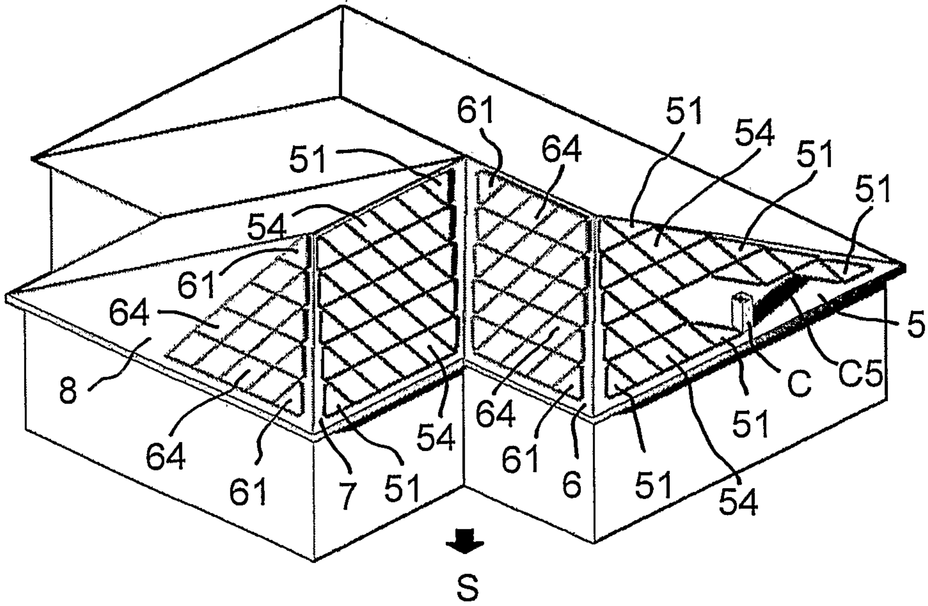
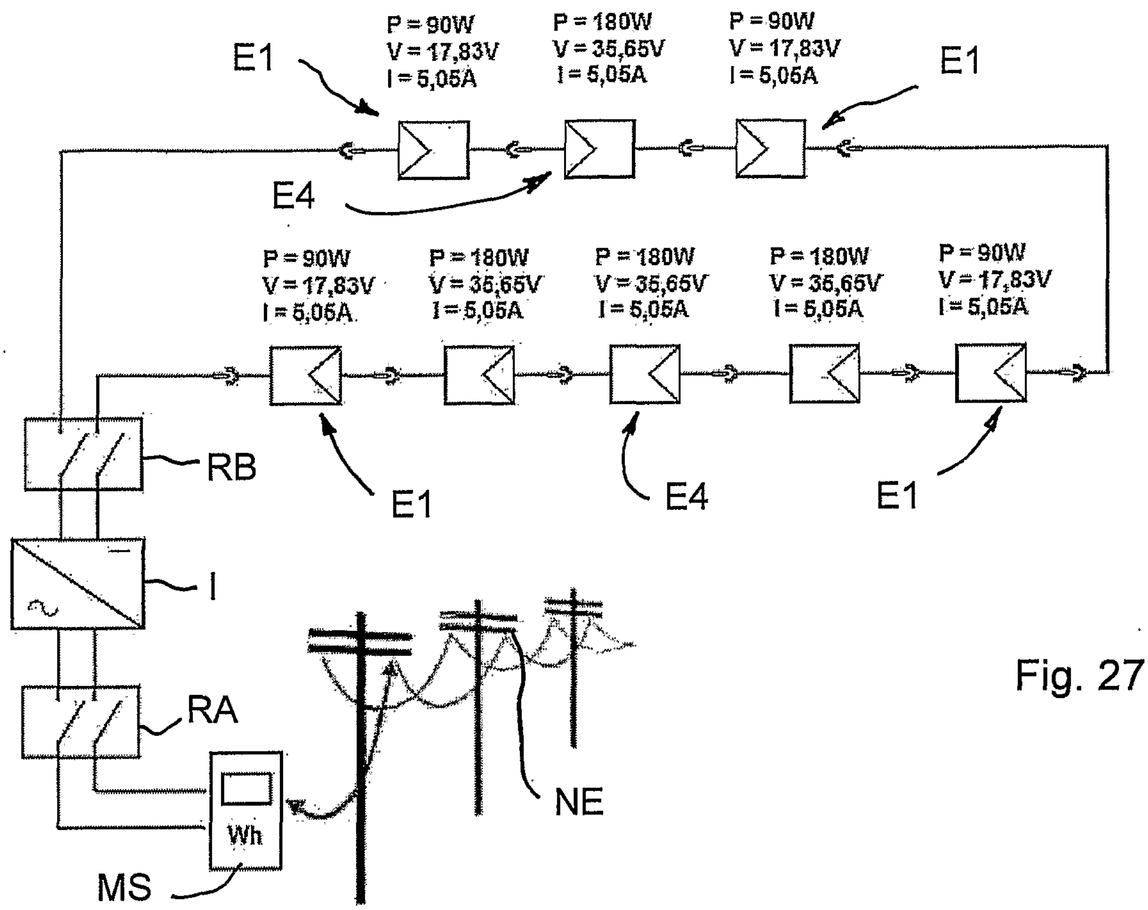


Fig. 25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I = 5,05A
P = 180W
V = 35,65V
I = 5,05A
P = 90W
V = 17,83V
I = 5,05A
E1
E1
E4
P = 90W
V = 17,83V
I = 5,05A
P = 180W
V = 35,65V
I = 5,05A
P = 180W
V = 35,65V
I = 5,05A
P = 180W
V = 35,65V
I = 5,05A
P = 90W
V = 17,83V
I = 5,05A
RB
E1
E4
E1
I
RA
Wh
NE
MS

Fig. 27

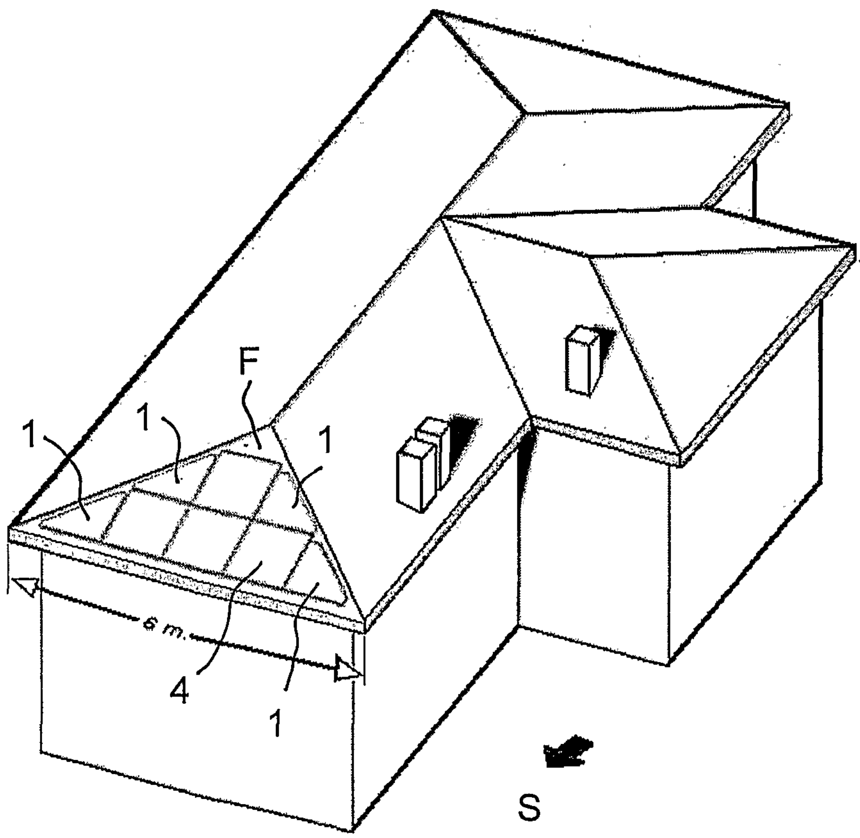
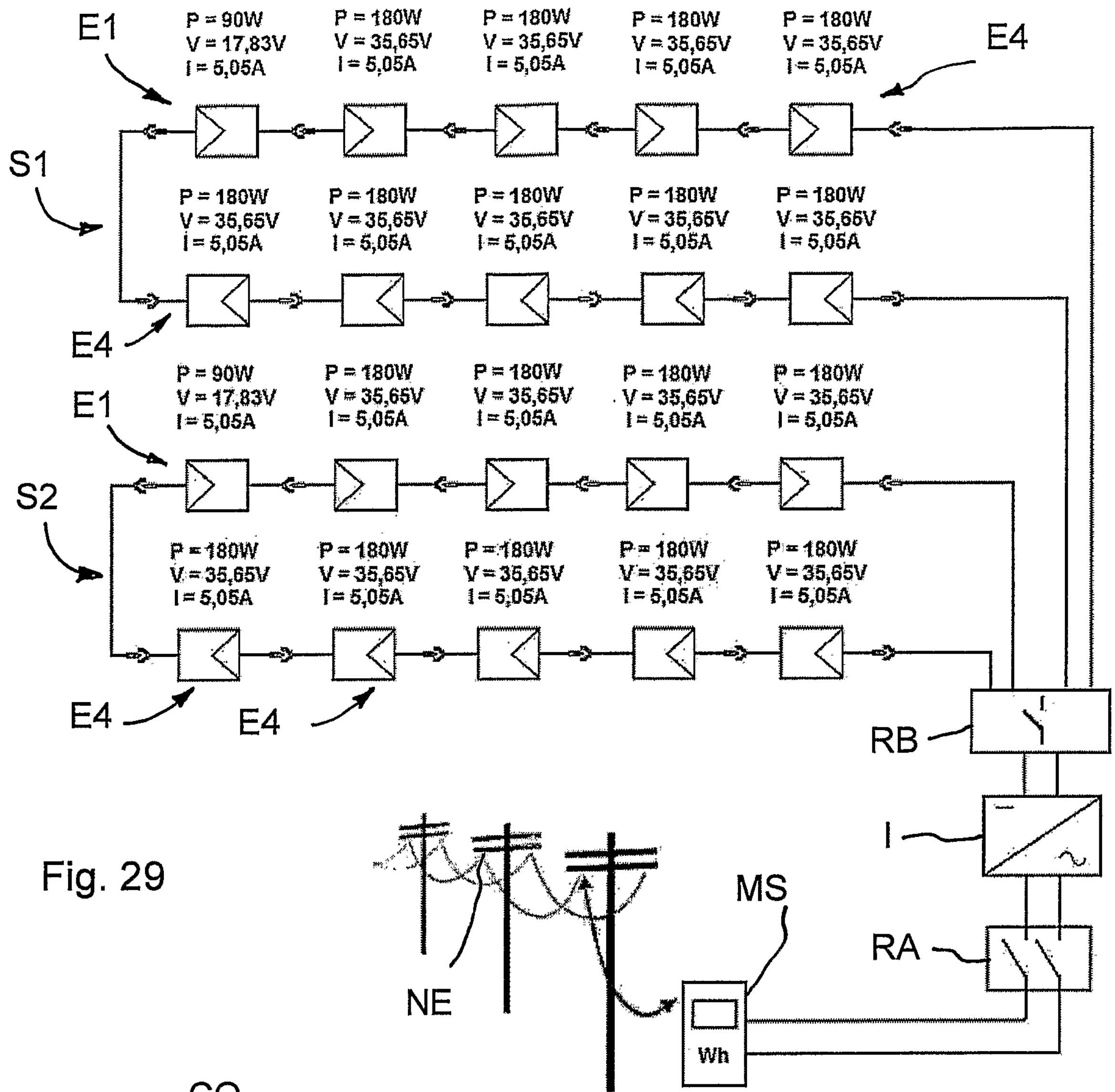

F
1
1
1
1
6 m.
4
1
S

Fig. 26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I = 5,05A
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V = 35,65V
I = 5,05A
E4
S1
E4
E1
S2
P = 90W
V = 17,83V
I = 5,05A
RB
I
RA
MS
NE
Wh

Fig. 29

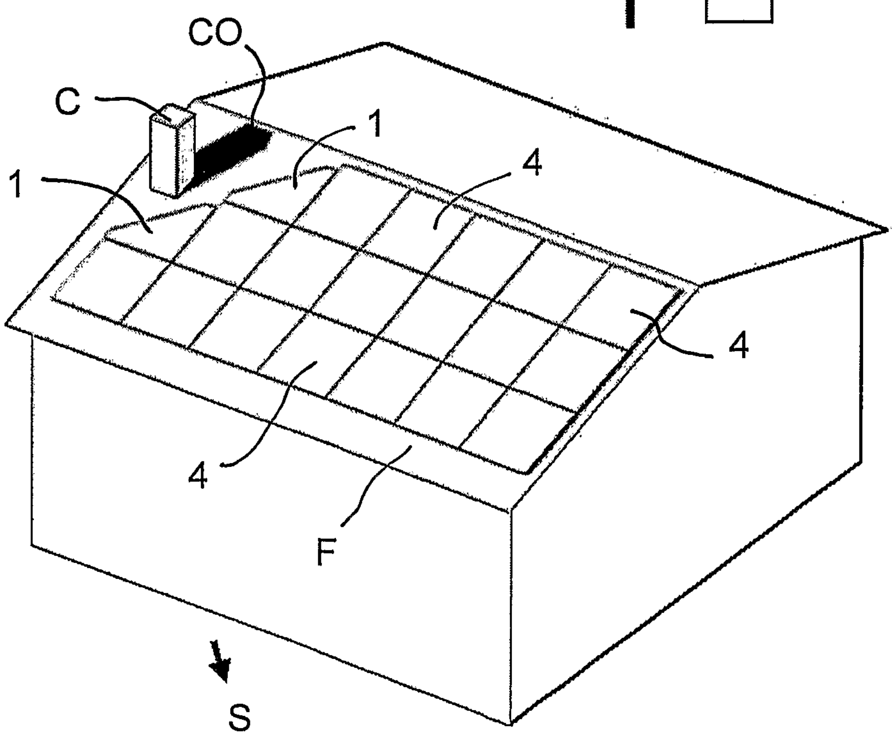
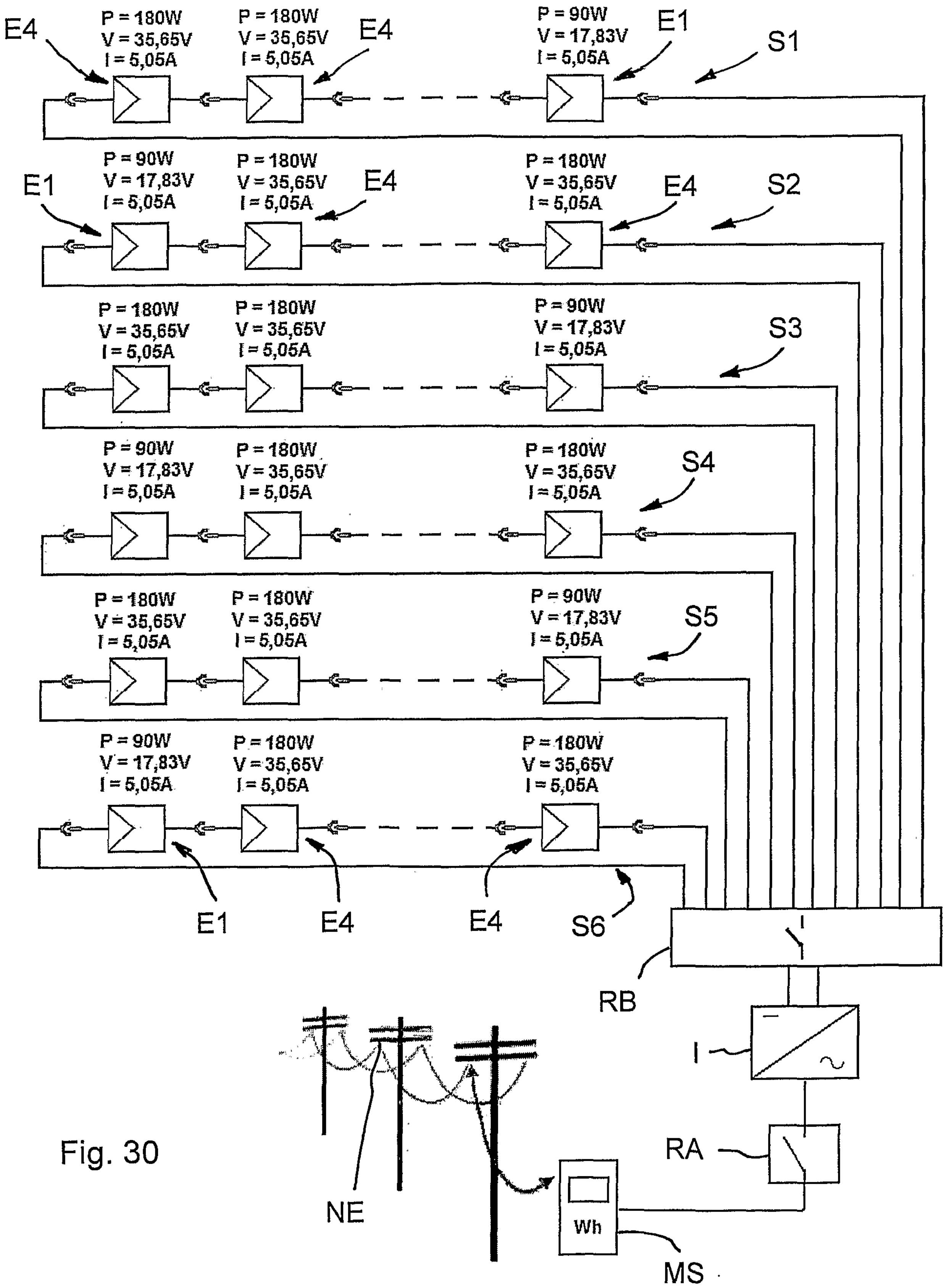

CO
C
1
4
F
S

Fig. 28



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I = 5,05A
E4
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E1
S1
E1
P = 90W
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I = 5,05A
P = 180W
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I = 5,05A
E4
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V = 35,65V
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E4
S2
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I = 5,05A
S3
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I = 5,05A
P = 180W
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S4
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I = 5,05A
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E1
E4
E4
S6
RB
I
RA
NE
Wh
MS

Fig. 30

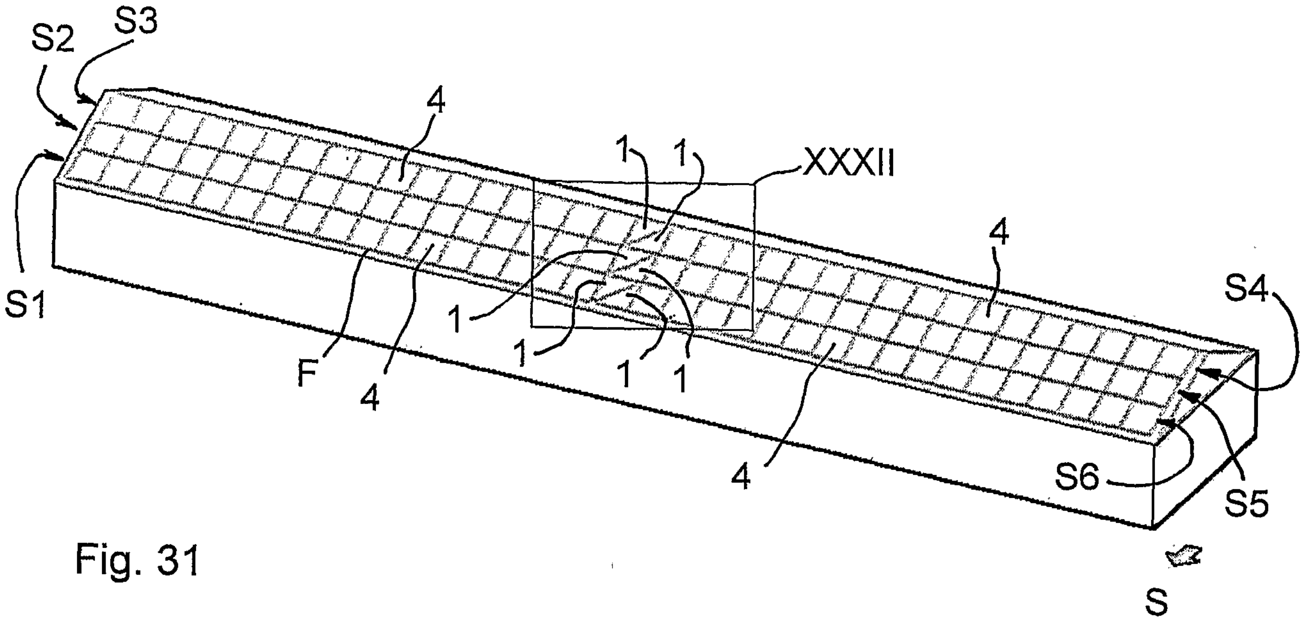

Fig. 31

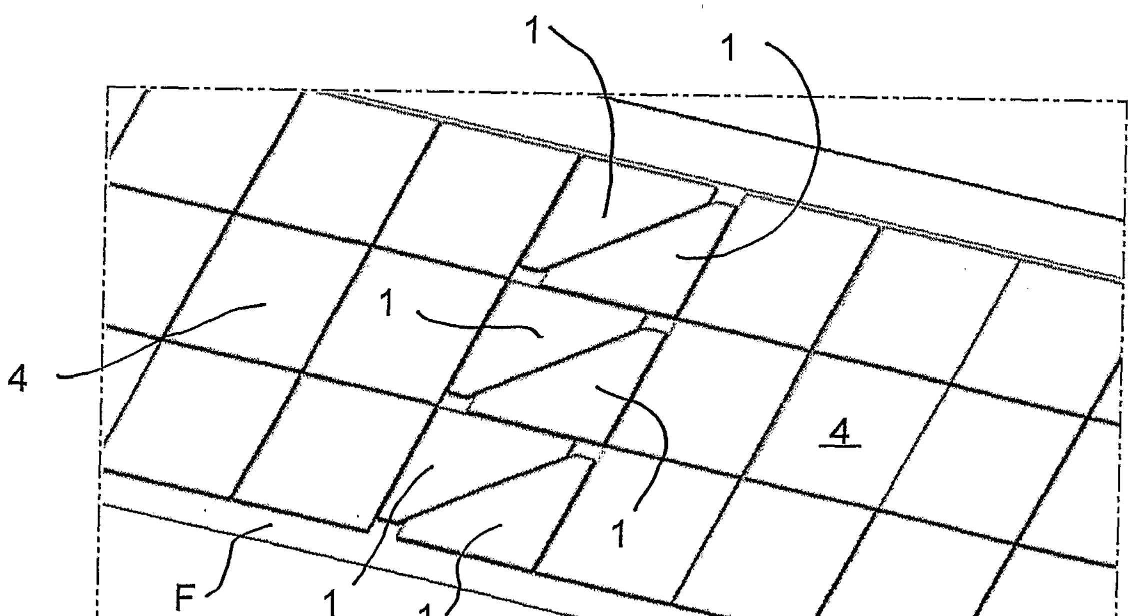

Fig. 32