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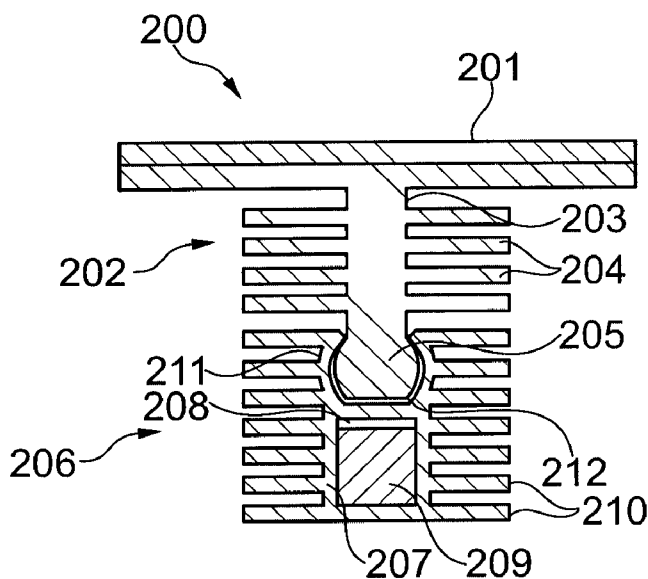


Fig. 2A

(57) Abstract: A solar module arrangement is provided
which comprises at least one solar module element (201);
and a cooling system (200), wherein the cooling system
(200) comprises a heat dissipation element (202) thermally
connected to the at least one solar module element (201);
and a heat storage element (206) thermally connectable to
the at least one solar module element (201).

WO 2016/124338 A1

Solar Module Arrangement and a Method Retrofitting a Solar Module Element

Technical Field

The invention relates to a solar module arrangement, in particular to a cooled solar module arrangement.

Furthermore, the invention relates to a cooling system for heat generating devices.

Beyond this, the invention relates to a method of retrofitting a solar module element.

Background

Both photovoltaic and also solar-thermal energy generation plants are known from the prior art. Both use the incident solar radiation to generate either electrical or thermal energy and supply it to a further consumer. So-called combination modules also exist, which allow a combination of photovoltaic and solar-thermal energy generation. In all modules, an orientation toward the sun which is a function of the geographical usage region is necessary to optimize the efficiency.

Typically, such modules comprise a plurality of photovoltaic cells which only convert a small amount of the incoming radiation energy into electric energy while a bigger amount is converted into heat. The generated heat will heat up the photovoltaic cell leading to a decrease in the electric output in voltage as well as in power.

From the prior art, e.g. WO 2014/203167 a solar module arrangement or photovoltaic (PV) power generation systems is known, wherein the system includes a PV module having an integrated frame structure, PV cell rows, solar tracking system, and cooling system. A protective cover may be included with the frame structure to form an enclosed area in which the PV cell rows, cooling system, and tracking system are placed, thereby protecting them from the elements. The cooling system may be a water circulation based cooling system, and the integrated frame of the PV module may be directly mounted on a

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foundation consisting of a water tank. The water tank may serve as the storage unit for the water cooling system, with the water from the tank being pumped through the cooling profiles at each cell row in the frame and then returned to the tank.

Summary

However, there may be a need to provide a solar module arrangement, a cooling system for a heat generating device and a method of retrofitting a solar module element which may have a high cooling ability while having at the same time a low complexity.

This need may be met by a solar module arrangement, a cooling system for a heat generating device and a method of retrofitting a solar module element according to the independent claims. Further exemplary embodiments are described in the dependent claims.

According to an exemplary aspect a solar module arrangement is provided which comprises at least one solar module element; and a cooling system, wherein the cooling system comprises a heat dissipation element thermally connected to the at least one solar module element; and a heat storage element thermally connectable to the at least one solar module element.

In particular, the heat storage element may be thermally connectable to the heat dissipation element, which in turn is connectable to the solar module element (more particularly to the photovoltaic cell(s) of the solar module element) so that the heat storage element may be (indirectly) coupled to the solar module element. It should be noted that the connectability may be a controlled or uncontrolled or fixed connection. In particular, the solar module elements may be photovoltaic elements and may comprise a plurality of photovoltaic cells, which may be arranged in a framed or frameless solar module element.

In particular, the cooling system may be a passive cooling system. The term "passive" may particularly denote a cooling system comprising no elements or units (e.g. a pump, like a water pump) supplied with (electrical) power or the like. In particular, the cooling system may be

free of a powered (liquid) pump for pumping a cooling liquid like water, for example. However, it should be noted that a cooling system may still be called “passive” in case a powered control unit is provided which controls a (powered) pump or (powered) actuator configured to couple and/or decouple the heat dissipation element and/or heat storage element from each other or from the solar module element. For example, the heat dissipation element and the heat storage element may be thermally coupled by a heat pipe which is a passive element but may be suitable to transfer the heat from the heat dissipation element to the heat storage element, may be coupled by a common body or housing and/or coupling features.

However, alternatively or additionally the cooling system may comprise electrically powered elements, like a ventilator or fan or a Peltierelement. Such active cooling elements may be controllable and may be switched on and off according to the needs. It should already be mentioned that the cooling system may be a retrofit package which can be combined with common regular module elements possibly even in case these are already installed, e.g. in a field array of a ground mounted installation.

The term “heat dissipation element” may particularly denote an element or unit which is configured or designed to dissipate or discharge heat from a heat generating element or device, e.g. the photo cell of a solar module element or an electrical transformer, to an ambient medium, e.g. air or ground. For facilitating a good heat dissipation the heat dissipation element has a high surface interfacing with the ambient medium. In particular, the heat dissipation element may comprise surface structures increasing the total outer surface, like cooling fins, cooling filaments or wires, or a cooling web. It should be noted that the heat dissipation element is in particular an element dissipating or discharging the heat to an ambient environment, e.g. the atmospheric or ambient air. In particular, the heat dissipation element is a part of a cooling system, i.e. a system used for cooling the solar module element, so that the heat discharged or dissipated cannot be technically used any

more.

The term “heat storage element” may particularly denote an element or unit configured to store a relative high amount of heat energy. Therefore, the heat storage element comprises or consists of a medium having a relatively high specific heat capacity. In principle, the dissipation to an ambient medium, e.g. the ambient air or ground, is relatively low due to a typically compact design having (compared to a heat dissipation element) a much lower (specific) outer surface. However, it should be mentioned that some additional structures increasing the outer surface (e.g. cooling fins) may be formed at the heat storage element as well.

According to another exemplary aspect a cooling system for a heat generating device is provided, wherein the cooling system comprises a heat dissipation element thermally connectable to a heat generating device; and a heat storage element thermally connectable to the heat generating device.

In particular, the heat generating device may be a solar module element or a transformer or any other device generating waste heat which has to be dissipated. The size and/or capacity of the cooling system may be adapted to the size of common solar module elements or surfaces of typical transformers or the like. Preferably the cooling system may be a passive cooling system. In particular, it may have a planar surface adapted to be thermally coupled to a planar backside of a solar module element or any other heat generating device. It should be mentioned that the heat storage element may be coupled directly to the heat generation device or may be indirectly coupled (e.g. via the heat dissipation device) to the heat generating device.

According to another exemplary aspect a method of retrofitting a backside of a solar module element with a cooling system is provided, wherein the method comprises providing a cooling system which comprises a heat dissipation element thermally connectable to the at least one solar module element; and a heat storage element thermally connectable to the at least one solar module element; and retrofitting the

cooling system to a backside of a solar module element.

In particular, the retrofitting may be performed by fixing the cooling system to the backside of the solar module element by screwing, pinning, gluing, soldering, a self-adhering process, adhering or any other suitable methods to fix and thermally coupling the two parts together.

By providing a solar module arrangement comprising solar module elements thermally connected to a heat dissipation element and a heat storage element at the same time it may be possible to reduce a size of the heat dissipation element while still enabling an efficient cooling. For example, the heat storage element may particularly be useful at higher temperatures, i.e. during times at which the sun is standing at its highest zenith angle over the solar module elements. At that times the waste heat production (of photovoltaic cells) is quite high, so the heat dissipation element typically is dimensioned to this daytime. However, in case of a hybrid cooling system comprising heat dissipation and heat storing elements the temperature peaks may be buffered by the heat storage elements which then, at lower ambient temperatures, convey the stored heat energy to the heat dissipation elements which dissipate the intermediately stored heat to the environment or itself may as well dissipate some heat energy to the environment.

A gist of an exemplary embodiment may be seen in providing a solar module arrangement comprising a cooling system which may particularly be useful for cooling photovoltaic cells during the time period of the highest energy production so that the performance and/or efficiency of the photovoltaic cells and thus of the solar module arrangement is increased. A basic principle may be to provide the solar module arrangement with a cooling system or cooling body which discharge the heat directly to the environment (e.g. ambient air) or (in particular at the phase of the highest energy production) buffering the heat and discharge or dissipate the heat time delayed (e.g. during night time). In particular, the cooling system may be a (passive) hybrid cooling system combining two principles, namely one component or element having a good thermal conductivity which may function as a heat

exchanger, i.e. dissipate waste heat to the ambient environment, and a second component or element functioning as a (buffering) heat storage. By combining these two principle it may be possible to keep the solar module elements (or more particularly the photovoltaic cell(s) of the solar module element) at a moderate temperature (in particular at noon) without increasing the passive cooling areas or surfaces (e.g. cooling fins). The stored heat may then be dissipated via the relatively small heat dissipation element during a time of the day where the ambient temperatures is lower or at night, so that the buffering capacity of the heat storage element is refreshed and restored for the next peak temperature, e.g. next noon.

In the following, further exemplary embodiments of the solar module arrangement will be explained. However, these embodiments also apply to the cooling system for a heat generating device and the method of retrofitting a solar module element.

According to an exemplary embodiment of the solar module arrangement the heat dissipation element comprises a material having a high heat conductivity coefficient.

In particular, the heat conductivity coefficient may be above a predetermined threshold. For example, the predetermined threshold may be about $10\text{W}/(\text{m}\cdot\text{K})$ preferably above $100\text{W}/(\text{m}\cdot\text{K})$. In particular, the heat conductivity coefficient of the material may be higher than the one of another material used for example for the heat storage element. Suitable materials, may be metals, metallic alloys, sintered materials or the like.

According to an exemplary embodiment of the solar module arrangement the heat dissipation element comprises a material selected out of the group consisting of: aluminum; copper; ceramics; silicon; graphite; sintered material, heat conductive plastics and mixtures thereof.

In addition, heat conductive liquid or ductile material, like heat transfer paste or thermal conductance paste may be used as well, which

may provide for an improved thermal coupling of the heat dissipation element to the solar module element and/or the heat storage element.

According to an exemplary embodiment of the solar module arrangement the heat storage element comprises a material having a high specific heat capacity.

In particular, the specific heat capacity may be above a predetermined threshold. For example, the predetermined threshold may be about 500 J/(kg·K) preferably above 2,000 J/(kg·K). In particular, the specific heat capacity of the material may be higher than the one of another material used for the heat dissipation element.

In particular, the material may be a material having a phase transition in the temperature range corresponding to temperatures typically achieved in the field of solar module arrangements, e.g. salts. For example, the phase transition temperature of such a phase change material (PCM) may be in the range of 0°C and 100°C, in particular, in the range of 20°C to 80°C, preferably in the range of 30°C to 60°C, e.g. in the range of 25°C to 50°C. It should be noted that a suitable solidification temperature of the PCM may be (in particular, a couple of °C, e.g. 5°C or 10°C) above the expected ambient temperature. Thus, it may be possible to ensure that the heat energy causing the phase transition is supplied by the photovoltaic cells (to be cooled) of the solar module element and not from the ambient air.

In particular, the heat capacity of a used heat storage element may be above 500 J/K, in particular above 1,000 J/K, preferably above 2,000 J/K, e.g. above 5,000 J/K. However, it should be noted that these values are of course dependent on the size or power generation of the respective solar module element(s) the heat storage element is associated with. For example, the heat capacity of the heat storage element may be in the range of 500 J/K to 1 MJ/K per installed kilowatt electrical (peak) power. However, it should be noted that in case of a latent heat accumulator the total heat storage capacity may be of course much higher.

It should be noted that the heat storage element may be thermally

and mechanically coupled to the solar module element. For example, the heat storage element may be attached or fixed to the backside of the solar module element and may be supported or carried together with the solar module elements in a field array. Thus, it may be different to a large water tank installed on ground.

According to an exemplary embodiment of the solar module arrangement the heat storage element comprises a material selected out of the group consisting of: water; paraffin; silicone; oil; grease, salts; and a combination thereof.

In particular, the salts may be phase change materials. In addition or alternatively organic materials like grain, fruit stones, wood may be used as well, which may be immersed into water oil or another fluid. Other possible options are mixtures of a solid and a liquid material, e.g. wet sand or wet timber.

According to an exemplary embodiment of the solar module arrangement the heat dissipation element and the heat storage element are formed by two different elements.

Alternatively, the heat dissipation element and the heat storage element may be formed by one single or combined element or unit. In this case the single or combined element may comprise or may be made of a material which has as well a relatively high coefficient of thermal conductivity and a high specific heat capacity, e.g. a wet timber product. Alternatively, the combined element may comprise parts of different material one having a high thermal conductivity while the other has a high specific heat capacity. For example, such a combined element may comprise heat conductive silicone in which phase changing material granulate embedded or incorporated in (micro) capsules. In particular, the single element may be a simple mat-like element which can be fixed, e.g. glued, to the back side of the solar module element. Such a fixing may be a retrofitting or backfitting to the backside of an already manufactured or even installed solar module element. In particular, a simple mat-like element may be sufficient (although the specific surface of such a mat-like element is often rather low) for dissipating or

discharging the heat, since, due to the buffering capacity, the heat may be discharged later on (during times when the waste heat generation is lower). However, it should be mentioned that also such a mat-like element may comprise additional cooling fins for increasing the specific (outer) surface.

Another possibility may be that the cooling system may be formed by elements of an installation system for the solar module elements. For example, a hollow profile of the installation system may be filled with a phase change material, or the heat dissipation element and/or of the heat storage element may be attached or mounted to the installation system. In particular, an installation system may comprise or may be formed by an aluminum or steel mounting structure or the like. Such a mounting structure or system may also be used to convey heat energy into the environment, e.g. into ground or external heat dissipating or storage elements.

According to an exemplary embodiment of the solar module arrangement the heat dissipation element is configured to dissipate thermal energy by one physical effect selected out of the group consisting of: radiation; heat conduction; and convection.

In particular, the radiation may dissipate or discharge the heat energy to the environmental air or medium via cooling elements or cooling structures like cooling fins or the like. Alternatively or additionally, the heat energy may be dissipated via heat conduction, e.g. into the ground the solar module arrangement is arranged on or mounted to. Furthermore, the heat energy may be dissipated via convection to the surrounding medium, like air or a further cooling medium.

According to an exemplary embodiment of the solar module arrangement the heat storage element comprises a cavity filled with a heat storing material.

In particular, the cavity may be formed by a single cavity filled with the heat storing material (in particular, a heat storing material having a high specific heat capacity) or may be formed by a plurality of sub-cavities filled with identical or different material. For example, the

cavity may be filled with water, paraffin, silicone or a mixture thereof. Alternatively the material may be formed by an emulsion or dispersion or a chemical compound. In particular, the heat storing material may be encapsulated in a cartridge. For example, the cavity or sub-cavities may form a honeycomb structure or any structure providing sufficient space to accommodate the material while reducing the amount of necessary material to build the structure but still providing sub-cavities enabling a flexible amount of heat storing material.

According to an exemplary embodiment of the solar module arrangement the at least one solar module element comprises a housing, wherein the cooling system is thermally coupled to the housing.

In particular, the cooling system forms a portion of the housing, e.g. a backside of the solar module element. Alternatively the cooling system may be separate to the housing but may be arranged partially within the housing. For example, the housing may comprise an opening through which a part of the cooling system extends. Another alternative may be that the cooling system is attached, e.g. mounted, glued, screwed, attached by needles or nails, adhered or a likewise fixed to the backside of the housing. It should be noted that it may be advantageous to provide a good thermal connection, e.g. by using metallic mounting (screws or nails) or a thermally conductive adhesive. For example, the screws or nails may penetrate the backside of the housing in order to provide a good thermal conductivity.

According to an exemplary embodiment of the solar module arrangement a backside of the at least one solar module element comprises a heat conductive material.

For example, the backside may comprise or may be made by a metallic material or a material in which heat conductive ceramics or plastics are mixed. Thus, a good thermal coupling may be achieved.

According to an exemplary embodiment the solar module arrangement comprises a plurality of solar module elements.

In particular, each of the plurality of solar module elements may comprise an own cooling system separate to the cooling systems of the

other solar module elements. Alternatively or additionally some or all of the solar module elements may have a common (single) cooling system. For example, the cooling system may comprise or may consist of a plane like or planar sheet like element or unit connected to a single or a plurality of solar module elements. In particular, such a plane or sheet like cooling system may cover the backside of a single or a plurality of solar module elements or its housing. It should be noted that further parts of the cooling system may be attached or implemented in such a carpet like element.

According to an exemplary embodiment of the solar module arrangement the cooling system is scalable.

In particular, the term “scalable” may particularly denote the fact that a cooling power or cooling ability may be scalable according to the needs. For example, additional heat dissipation elements and/or heat storage elements may be combined or attached together to form a single cooling system. In particular, the scalability may be given by providing a plurality of cavities or sub-cavities which can be filled or emptied according to the cooling needs, e.g. by inserting and pulling out cartridges.

According to an exemplary embodiment of the solar module arrangement the heat dissipation element and the heat storage system are configured to be coupleable and decoupleable from each other.

In particular, the two elements may be substantially thermally and/or mechanically decoupled by an air gap or a gap filled by a suitable fluidic or solid medium thermally decoupling the two elements from each other, e.g. oil, gas, gel, plastic foam or the like. In case of a fluidic medium different pressures, e.g. pressure below atmospheric pressure or above atmospheric pressure may be used. The use of different pressures may as well be used to thermally decouple or couple the two elements from or to each other. However, the two elements may still touch each other at some points or small areas even in the decoupling state. Alternatively, the two elements may be fixedly connected or coupled to each other, e.g. may form a single cooling body.

According to an exemplary embodiment of the solar module arrangement the solar module arrangement comprises a control unit, wherein the control unit is configured to control a process decoupling and coupling the heat dissipation element and the heat storage element.

The control unit may (also or alternatively) be configured to couple and decouple the total cooling system from the at least one solar module element. In particular, the control unit may be configured in such a way that the heat storage element is coupled and/or decoupled to the solar module element at a later or earlier time than the heat dissipation element. It may also be possible that the heat dissipation element is coupled to the solar module element all the time (fixed thermal connection) and only the heat storage element is coupleable and decoupleable.

Preferably, the coupling is performed in such a way that the heat dissipation element and the heat storage element have a large contact area directly coupling the two with each other in the coupling state in order to provide a good heat transfer. Moreover, additional material or substances may be used in order to improve the thermal coupling and/or to increase the contact area, e.g. heat conductive paste. Alternatively to a direct coupling the coupling may be by use of suitable fluidic, solid or combined media, e.g. oil filled with graphite.

According to an exemplary embodiment of the solar module arrangement the control unit is configured to perform the decoupling or coupling process based on a temperature measurement.

In particular, the decoupling and coupling process (e.g. by use of a control or trigger signal) may be based on a temperature difference between the heat dissipation element and the heat storage element. Further, possible parameter used for controlling the decoupling/coupling process may be absolute temperatures, like ambient temperature, or temperature of solar cells of the solar module element, day time, position of the sun, intensity of solar irradiation, and so on.

According to an exemplary embodiment the solar module arrangement further comprises a heat cycle thermally connected to the

cooling system.

By connecting the cooling system onto a heat cycle it may be possible to use the (waste) thermal energy for other processes. For example, the heat cycle may be used for heating (e.g. in case the solar module arrangement is set up on a roof of a dwelling house or company building) or may be used to transfer the thermal energy to an (external) latent heat accumulator so that it may be used in winter time to keep the solar module arrangement ice-free. Alternatively or additionally the heat radiation of the heat dissipation element may be used to generate electrical energy as well, e.g. by using the radiation to activate erbium atoms.

According to an exemplary embodiment of the solar module the heat storage element comprising a coupling feature configured to be coupled to the heat dissipation element and/or the at least one solar module element.

Examples for such a coupling feature may be structural features, like a projection and/or recess. In particular, such coupling features may have a shape matching complementary coupling features at the corresponding element, e.g. the heat dissipation element and/or the solar module element. For example, the coupling feature may be an open cavity having a round, trapezoidal triangular, or rectangular cross-section, while a corresponding complementary matching coupling element of the corresponding element may have a spherical, a pyramidal, or cuboid shape. In particular, a size or dimension of the cavity may be slightly larger than the size of the complementary element at lower temperatures (e.g. below a predetermined threshold temperature, like typical night temperatures, e.g. below 20°C). Thus, the coupling features may abut each other only at small portions if at all. At higher temperatures, e.g. at the temperature corresponding to a temperature being in the range of noon temperatures of the solar module element (e.g. above 40°C) so that, due to thermal expansion, the coupling features may abut each other at a greater area. Thus, a simple way of coupling and (substantially) decoupling of the heat dissipation element

and the heat storage element may be enabled.

Brief Description of the Drawings

The aspects defined above and further aspects are apparent from the examples of embodiment to be described hereinafter and are explained with reference to these examples of embodiment.

In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale. Instead emphasis is generally being placed upon illustrating the principles of the invention. In the following description, various exemplary embodiments are described with reference to the following drawings, in which:

Figs. 1 schematically illustrates a cooling system according to an exemplary embodiment;

Figs. 2A to 2C schematically illustrate the operation of a cooling system according to another exemplary embodiment;

Fig. 3 shows graphs illustrating schematically an effect of a cooling system according to an exemplary embodiment; and

Fig. 4 describes a flowchart of a method of retrofitting a solar module element.

Detailed Description of Embodiments

In the following further exemplary embodiments of a solar module arrangement, a cooling system for a solar module arrangement and a method of coupling a cooling system to a backside of a solar module element will be explained. It should be noted that the description of specific features described in the context of one specific exemplary embodiment may be combined with others exemplary embodiments as well.

Fig. 1 schematically illustrate a cooling system 100 according to an exemplary embodiment. In particular, Fig. 1 shows a backside of a solar

module element 101 to which a cooling system 102 is attached. The cooling system 102 comprises a housing 103 having formed on an outer surface thereof a plurality of cooling fins 104. The housing and the cooling fins may be formed of one or a mixture of different materials having a good thermal conductivity, e.g. above a given threshold (e.g. above $10\text{W}/(\text{m}\cdot\text{K})$). Suitable materials may be metal, like aluminum or copper, graphite, or heat conductive plastic, like silicone or the like. These cooling fins provide for a large contact surface of the heat dissipation element with an ambient medium like ambient air and may thus efficiently cooling the solar module element. In the housing a cavity 105 is formed which is filled with a material 106 having a high specific heat capacity, e.g. $500\text{ J}/\text{kg}\cdot\text{K}$. Suitable materials may be oil, water, silicone oil, grease which may be mixed or filled with other materials like grain, fruit stones, wood. Advantageous materials may also be phase change materials, like paraffins or salts. In particular, phase change materials having the respective phase transition temperature in the region of the daily temperature cycle (caused by different intensity of the solar radiation), e.g. between 20°C and 60°C , may be advantageous. The filled cavity forms a heat storage element which is permanently thermally coupled to the heat dissipation element.

It should be noted that of course the depicted one cavity may be divided into a plurality of sub-cavities which may be filled with the same or different materials. Instead of the mentioned fluid materials also solid materials or emulsions and dispersions may be used to fill the cavity to act as a heat storing medium.

In general the cooling system according to Fig. 1 comprises a single cooling body (having a cavity formed therein) functioning as a body or corpus of the heat dissipation element and the heat storage element (a medium filled in the cavity), i.e. may form a combined heat dissipation and heat storage element.

Figs. 2A to 2C schematically illustrate the operation of a cooling system according 200 to another exemplary embodiment. In particular, Fig. 2 shows the operation of a passive cooling system which can perform

a coupling and decoupling action automatically depending on the temperature.

In particular, Fig. 2A shows the cooling system 200 attached to a backside of a solar module element 201 and comprising two separate elements. A first element 202 is a heat dissipation element comprising a main body 203 to which a plurality of surface increasing structures 204, like cooling fins are attached or formed thereon. Furthermore, a coupling feature 205 is formed or attached to an end of the main body. According to Fig. 2A this coupling feature is formed by a roughly spherical form but it may take any suitable other geometrical form as well. The heat dissipation element is shown to be fixedly connected to the backside of the solar module element 201 but may as well be coupleable and decoupleable from the same.

A second element 206 of the cooling system is similar to the one shown in Fig. 1. In particular, the second element comprises a housing 207 forming a cavity 208 in which a material or matter 209 having a high specific heat capacity is filled. Thus, the second element forms a heat storage element of the cooling system. In addition further cooling fins 210 are formed at the outside of the housing of the second element 206 as well further increasing a contact interface to the environment. Furthermore, a coupling feature 211 is formed at the heat storage element as well having a form or shape substantially complementary to the one of the coupling feature 205 of the heat dissipation element 202. In the embodiment of Fig. 2 the coupling feature 211 of the heat storage element 206 is formed by a cavity roughly having a spherical shape. The materials of the embodiment of Fig. 2 may be the same as described in the context of Fig. 1. It should further be noted that the further cooling fins 210 are optional.

In particular, Fig. 2A shows the cooling system in a first state, e.g. in the morning, when both elements are relatively cold, i.e. not heated by waste heat of the solar module element 201. At this point in time or state, a small gap 212 is given between the two coupling features 205 and 211 substantially thermally decoupling the heat dissipation element

202 and the heat storage element 206 although a small contact point or ring is given between the two elements.

Fig. 2B shows the cooling system of Fig. 2A at another state, namely a state or point in time at which the heat dissipation element 202 is warmed up due to increasing solar radiation, e.g. at noon or some time before noon, wherein the degree of heating up depends on the relative sizes of the solar module element (and the specific solar radiation at that day) and the performance or size of the heat dissipation element. At this another state the two elements 202 and 206 are thermally coupled to each other, i.e. the gap is reduced or has disappeared. The reduction of the gap is due to a thermal expansion of the spherical coupling feature 205 due to the increasing temperature of the heat dissipation element 202 which is thermally coupled (directly) to the solar module element and thus is heated up by waste heat. Due to this thermal expansion the two coupling features abut each other at a great area providing for a good thermal coupling. At this point in time or state the heat storage element may be heat up absorbing waste energy. Thus, at the point in time at which the generation of waste heat is highest the heat storage element 206 may absorb and store waste heat. This absorption of waste heat may reduce the load off the cooling fins 204 to dissipate the waste heat to the surrounding environment. Therefore, it may still be possible that, although the dissipation area of the cooling fins is not sufficient in order dissipate or discharge the total amount of waste heat generated, the temperature of the solar module element is kept at an acceptable level. Thus, the heat storage element 206 may act as a buffer for storing heat energy.

Fig. 2C shows the cooling system of Fig. 2A at yet another state, namely a state or point in time at which the heat dissipation element 202 is cooled down again (due to heat dissipation) while the heat storage element 206 still has a high temperature due to the high heat capacity of the heat storage element. This may correspond to a time at which the radiation of the sun (and thus the generation of waste heat) is reduced again, e.g. during evening or cloudy periods. According to the

embodiment of Fig. 2 and in particular, the design of the coupling features 205 and 211 the temperature distribution or states of the two elements 202 and 206 causes that the two coupling features are (substantially) decoupled again since the gap 212 is formed again. In the state of Fig. 2C the gap may even be larger than in the state of Fig. 2A, since at this point in time, the heat storage element 206 may be hotter (and thus the cavity of the coupling element 211 may be larger) than the heat dissipation element 202.

It should be noted that the cooling system shown in Fig. 2 may comprise more than one heat storage elements which may be coupled to each other with identical or similar coupling features as described above. For example, the heat storage element 206 may comprise a second coupling feature (e.g. as the coupling feature of the heat dissipation element 202) at the side opposite to the one the coupling feature 211 is formed on so that a second heat storage element may be attached to the second coupling feature. Thus, a kind of chain of heat storage elements may be achieved. However, other coupling methods are also possible, like simply gluing or screwing the different heat storage and/or heat dissipation elements together.

Fig. 3 shows graphs illustrating schematically an effect of a cooling system according to an exemplary embodiment. In particular, Fig. 3 shows a schematic temperature course during one day (e.g. summer time). Graph 300 illustrates the ambient air temperature during a day increasing from morning till some time after noon and then decreasing again. Graph 301 shows a principle course of a temperature of photovoltaic cells of a solar module, which rises steeply during the morning up to temperatures high above the ambient temperature and then dropping down again.

Graph 302 shows, in contrast, a temperature of photovoltaic cells of a cooled solar module. During the morning the temperature of the cooled solar module rises but less steep than the rise of the uncooled solar module and steeper than the ambient temperature. Depending on the size or dimension of the used cooling system a maximum

temperature level is reached before noon. At this point in time the additional waste heat generated by the solar module is buffered by the heat storage element leading to the fact that the temperature is not (or at least not substantially) rising any more. Then at a later time during the day (or even at night depending on the dimensions of the heat dissipation and/or heat storage elements) the heat storage element transfers its stored heat energy either back to the heat dissipation element and/or dissipate the energy itself. Thus, the temperature of the cooled solar module starts to drop.

As can be seen in the principle plot of Fig. 3 in particular the temperature peak about noon is truncated, which is advantageous since at that daytime the radiation of the sun is highest so that the energy production at the highest peak is less reduced by overheating of the photovoltaic cells. Possibly leading to a substantially improved total electric energy production.

Fig. 4 describes a flowchart of a method 400 of retrofitting a solar module element. In particular, the method 400 comprises providing a cooling system which comprises a heat dissipation element thermally connectable to the at least one solar module element; and a heat storage element thermally connectable to the at least one solar module element (step 401). Subsequently, the cooling system is coupled to a backside of a solar module element particularly to a solar module element which is already installed in a solar module arrangement, e.g. a ground mounted installation. The coupling may be performed by gluing, nailing, screwing, by way of an adhesive, e.g. by providing a self-adhesive layer to the cooling system. The cooling system may comprise a mat-like layer configured or suitable to be fitted to the backside of one or a plurality of solar module elements.

Summarizing according to an exemplary embodiment a cooling system may be provided which is based on two different elements or effects. On the one side a heat dissipation element is provided configured to discharge heat generated by a solar module element, (photovoltaic cells of the same) via a relative great outer surface (which may be

increased by surface structures like cooling fins or cooling filaments) or to the ground the solar module element is installed at. Preferably, this heat dissipation element is directly coupled or fixed to the backside of the solar module element. It may even replace a backside of a housing of the solar module element or may pass through the backside housing. The (backside of the) housing may particularly include some materials having a good heat conductivity (e.g. heat conducting ceramics). The size, dimension or number of the heat dissipation element(s) may be adapted or adjusted to the waste heat generation of the solar module element. For example, the size may be smaller, (substantially) identical, or larger than a base size of the solar module element. In particular, the heat dissipation elements, directly coupled to the solar module element may have the size of several solar module elements and have the shape of a carpet-like layer suitable to be fixed to a backside of several (PV) modules. However, it may have the size of a single or several photovoltaic cells.

In addition a heat storage element is provided which may be coupled to the heat dissipation element and/or to the solar module element. Such a heat storage element comprises a material which has a high specific heat capacity and forms a buffer storage for peak temperatures at which the heat dissipation element is not powerful enough to discharge all newly generated waste heat.

It should be mentioned that preferably the heat dissipation element and the heat storage element may be scaleable, e.g. by providing the possibility to couple a plurality of elements together. In particular, one or both types may be designed in a modular form. For example, different numbers of heat energy storage cartridges may be filled in the heat storage element or a different number of heat storage elements may be coupled to each other, e.g. in the form of a chain.

The design or dimensioning of the performance or capability of the two components (dissipation and storage) may be adapted according to the specific needs or requests. Preferably, the dissipation element and the storage element are dimensioned with respect to each other that the

temperature of the solar module element (in particular the photovoltaic cell) is kept at a (substantially) constant relatively cool temperature level, e.g. below 45°C, preferably below 40°C, e.g. about 35°C. However, it should be noted that these temperature levels may of course depend on the installation place, the degree of latitude, climate zone, etc. In principle the temperature level may be in the range of the mean summer temperature increased by a couple of °C. Alternatively the dissipation element may be over-dimensioned with respect to the storage element leading to the fact that the storage element may particularly buffer short time temperature spikes. However, it may be as well that the storage element may be over-dimensioned leading to the fact that the stored heat energy may be kept for a long time in the storage element.

In general, the cooling system according to such an exemplary embodiment may form a hybrid cooling system suitable to keep the temperature of a solar module element at a (relatively) lower temperature level (particularly) at about noon, which may lead to the fact that a higher amount of electric energy is generated. In particular, since at noon the electric energy production of the photovoltaic cells is typically highest, the reduction or avoiding of temperature spikes or peaks at noon may increase the total electric energy production even when (due to the heat storage element) the temperature of the solar module element may be higher at later hours.

It should also be noted that the term “comprising” does not exclude other elements or features and the “a” or “an” does not exclude a plurality. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs shall not be construed as limiting the scope of the claims. While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and

range of equivalency of the claims are therefore intended to be embraced. Throughout the whole description the word "exemplary" is used to mean "serving as an example, instance, or illustration". Any embodiment, aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or designs.

Claims

1. A cooled solar module arrangement comprising:
at least one solar module element; and
a cooling system comprising:
a heat dissipation element thermally connected to the at least one solar module element; and
a heat storage element thermally connectable to the at least one solar module element.
2. The solar module arrangement according to claim 1, wherein the heat dissipation element comprises a material having a high heat conductivity coefficient.
3. The solar module arrangement according to claim 1 or 2, wherein the heat dissipation element comprises a material selected out of the group consisting of:
aluminum;
copper;
ceramics;
silicon;
sintered material;
graphite;
heat conductive plastics; and
mixtures thereof.
4. The solar module arrangement according to any one of the claims 1 to 3, wherein the heat storage element comprises a material having a high specific heat capacity.
5. The solar module arrangement according to any one of the claims 1 to 4, wherein the heat storage element comprises a material selected out of the group consisting of:

water;
paraffin;
silicone;
oil;
grease;
salts; and
a combination thereof.

6. The solar module arrangement according to any one of the claims 1 to 5, wherein the heat dissipation element and the heat storage element are formed by two different elements.
7. The solar module arrangement according to any one of the claims 1 to 6, wherein the heat dissipation element is configured to dissipate thermal energy by one physical effect selected out of the group consisting of:
 - radiation;
 - heat conduction; and
 - convection.
8. The solar module arrangement according to any one of the claims 1 to 7, wherein the heat storage element comprises a cavity filled with a heat storing material.
9. The solar module element according to any one of the claims 1 to 8, wherein the at least one solar module element comprises a housing, wherein the cooling system is thermally coupled to the housing.
10. The solar module arrangement according to claim 9, wherein a backside of the at least one solar module elements comprises a heat conductive material.
11. The solar module arrangement according to any one of the claims

1 to 10, comprising a plurality of solar module elements.

12. The solar module arrangement according to any one of the claims 1 to 11, wherein the cooling system is scalable.

13. The solar module arrangement according to any one of the claims 1 to 12, wherein the heat dissipation element and the heat storage system are configured to be coupleable and decoupleable from each other.

14. The solar module arrangement according to claim 13, wherein the solar module arrangement comprises a control unit, wherein the control unit is configured to control a process decoupling and coupling the heat dissipation element and the heat storage element.

15. The solar module arrangement according to claim 14, wherein the control unit is configured to perform the decoupling or coupling process based on a temperature measurement.

16. The solar module arrangement according to any one of the claims 1 to 15, further comprising a heat cycle thermally connected to the cooling system.

17. The solar module arrangement according to any one of the claims 1 to 16, wherein the heat storage element comprising a coupling feature configured to be coupled to the heat dissipation element and/or to the at least one solar module element.

18. Cooling system for a heat generating device, the cooling system comprising:

a heat dissipation element thermally connectable to a heat generating device; and

a heat storage element thermally connectable to the heat

generating device.

19. Method of retrofitting a backside of a solar module element with a cooling system, the method comprising:

providing a cooling system comprising:

a heat dissipation element thermally connectable to the at least one solar module element; and

a heat storage element thermally connectable to the at least one solar module element; and

coupling the cooling system to a backside of a solar module element.

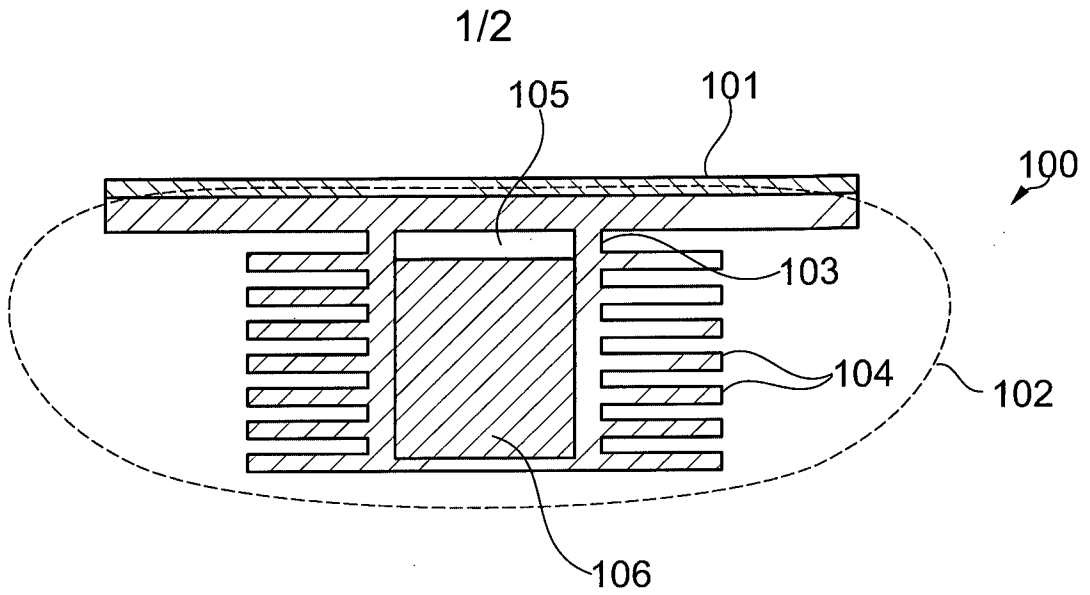


Fig. 1

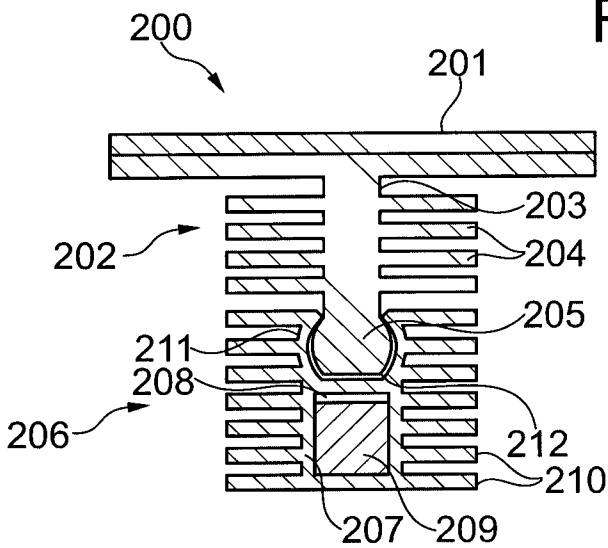


Fig. 2A

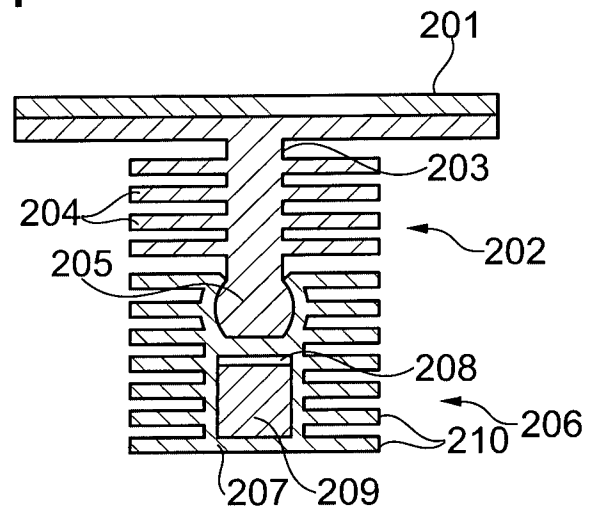


Fig. 2B

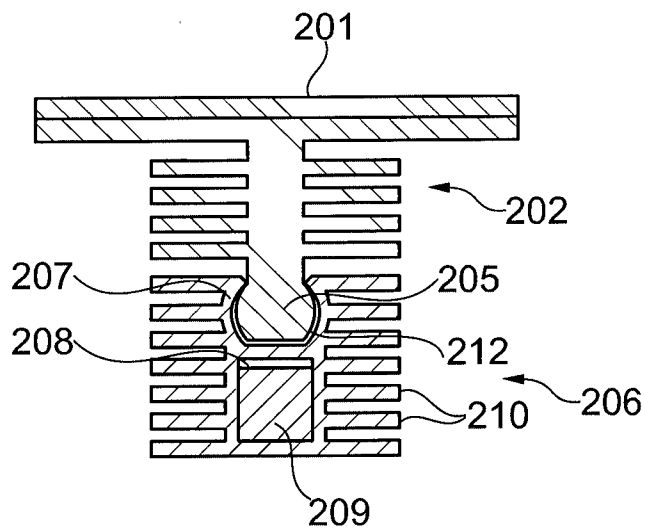


Fig. 2C

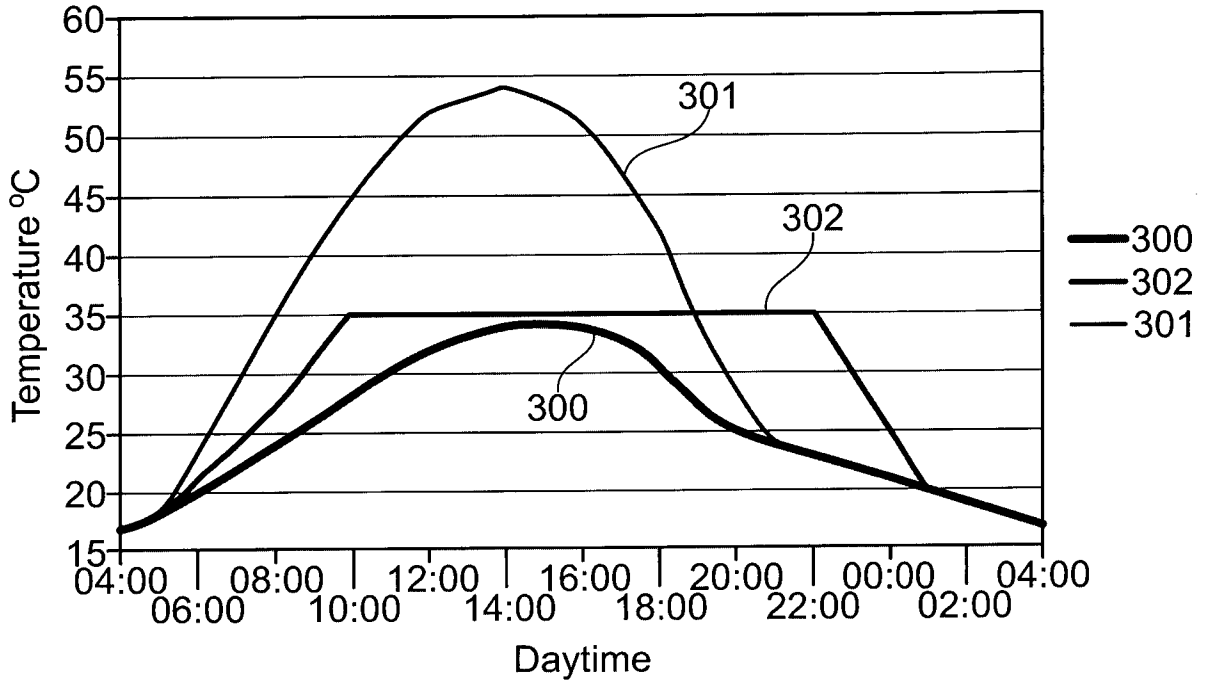


Fig. 3

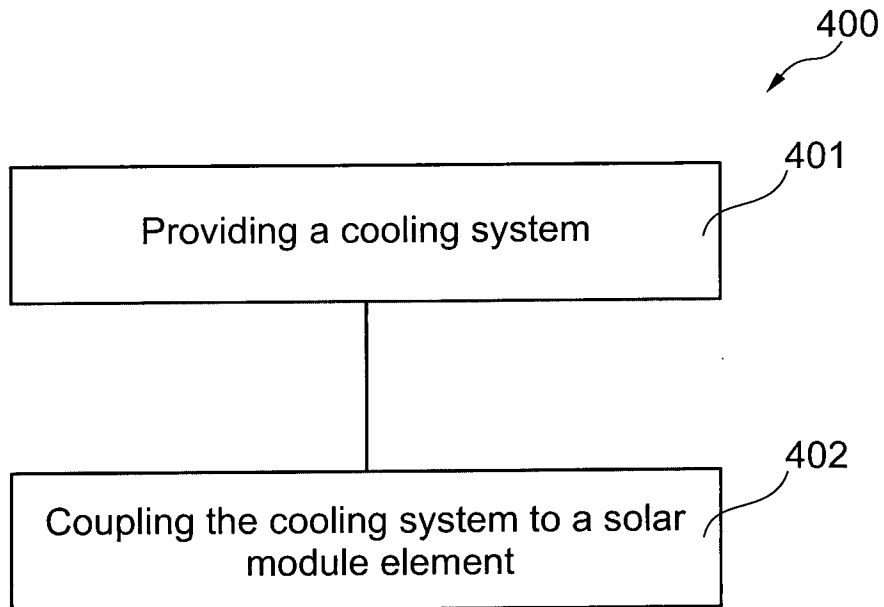


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/000225

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F24J2/34 F24J2/40 F24J2/46 H02S40/42
 ADD.
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 F24J F28F H02S F28D

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
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Date of the actual completion of the international search 22 June 2016	Date of mailing of the international search report 15/07/2016
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Beltzung, Francis
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International application No
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