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Invention Article

Integrated apparatus for supporting and cooling a photovoltaic panel

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ABSTRACT

The patented integrated Thermoelectric Generator (TEG) cooling system efficiently and space-savingly removes heat from solar cells during periods of high solar radiation. Unlike existing products that utilise the Peltier and Seebeck effect, in the patented system the Seebeck effect occurs internally in the heat sink itself, which acts entirely as a carrier for the cells, and only a small part of the removed heat is used to provide the required temperature difference. The invention results in a clear simplification of solar cell cooling and thermoelectric conversion technology. This also leads to cascading economic advantages in terms of overall system costs. We have started extensive research into new innovative and efficient materials to further improve the efficiency of the system and provide an increasingly competitive product for the market..We are looking for collaborators, joint-venturers and investors.

Specifications Table

Subject code	2102 – Energy Engineering and Power Technology
Specific subject area	PV power plants; Combinations of PV energy systems with other systems for the generation of electric power
Industry code	H-Electricity
Details of inventors	GIAMPIETRO FABBRI (University of Bologna, giampietro.fabbri@unibo.it) GREPPI MATTEO matteo.greppi2@unibo.it (University of Bologna, matteo.greppi2@unibo.it)
Dates of invention	Conception: 2016 Disclosure: 2018 https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2020115651&_cid=P12-LIOFI7-72220-1
Patent details	Patent owner: University of Bologna Patent attorney or agent: Bugnion S.p.A. Link to patent: https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2020115651&_cid=P12-LIOFI7-72220-1
Intended use	We intend to commercialize and license also temporary the invention.
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Related research article	Matteo Greppi, et al. "Integrated PV-TEG Cooling System and Support." International Journal of Engineering Science Invention (IJESI), Vol. 10(01), 2021, PP 21–26.

1. Value of the invention

The invention relates to a support and cooling apparatus for photovoltaic panels which has the following features:

- significant simplification of solar cell cooling technology and of thermoelectric conversion using the Seebeck effect.
- robust and compact integrated heat exchanger with small footprint.
- independence between heat exchange efficiency and thermoelectric generation efficiency.
- the Seebeck effect occurs within the same heat exchanger that acts as support and cooler for the photovoltaic cells.

These features result in the following advantages:

- overall system cost reduction.
- optimisation of the overall energy efficiency of the entire system.
- The end users targeted by this solution (private individuals, companies, public administration,…) are those who wish to optimise the photovoltaic production of their plant and at the same time obtain auxiliary electricity production using an efficient system with a small footprint.

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- Direct and indirect applications arising from the present invention relate to the creation of integrated thermoelectric cooling systems that optimise power density (where space is limited) for use as brand new systems or as retrofit solutions for existing photovoltaic systems.

2. Invention description

The core of the proposed integrated module (Fig. 1) consists of thermoelectric legs interconnected by means of press-fit joints, so that thermocouples are much more compact and simple to construct and assemble. The structure includes a support for the heat exchanger (the purpose of which is to cool the photovoltaic panel) and a fully integrated thermoelectric generator. In addition, the integrated cooling system is used as a support for the solar panel and can be adapted to different requirements due to its modularity. Compared to the state of the art regarding all photovoltaic cooling systems and thermoelectric generation equipment, the innovative prototype is smaller in size, more compact and easier to install. The aim of the invention [1] is to solve the technical problems of commercially available systems through the integrated combined production of photovoltaics and thermoelectricity, achieving a substantial increase in compactness and robustness compared to existing solutions. The patented prototype presents a clear independence between the efficiency of the heat sink and the efficiency of thermoelectric generation. The efficient and compact final integration is achieved by the fact that the Seebeck effect occurs within the heat exchanger itself, which acts as a support and cooling element for the solar cells. The proposed solution also allows the use of a slot system for fixing the electrical contacts, which reduces the number of screws and the overall space required for the system.

The integrated structure (Fig. 2) for supporting and cooling a photovoltaic panel (100) comprises in a preferral embodiment: a baseplate, configured to be mounted on a roof or on the ground; a top plate, the photovoltaic panel (10) being operatively rested on the top plate; a structure interposed between the baseplate and the top plate, to exchange heat with the photovoltaic panel (10) through the top plate, and including a first element (400A) made of a first material which is electrically conductive and has a first value of Seebeck coefficient, and a second element (400B) made of a second material which is electrically conductive and has a second value of Seebeck coefficient, different from the first value. The first material can be a P doped semiconductor, such as inorganic commercial Bi_2Te_3 (Bismuth Telluride - Seebeck coefficient 230 μV/K a 300 K) or preferably organic ones adopted for incoming researches, while the second one can be a N doped semiconductor, (such as commercial PbTe (Lead Telluride - Seebeck coefficient 187 μV/K a 300 K) or preferably organic ones adopted for incoming researches. In this way, the two Seebeck coefficients have opposite signs, thus enhancing the thermocouple effect. The first element and the second element are connected in order to allow the supplementary electric

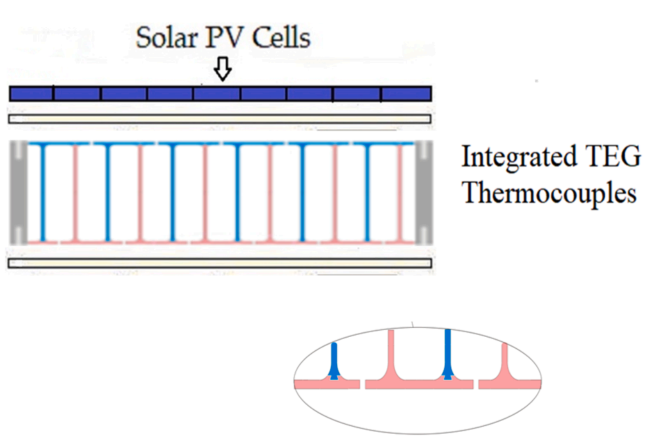

Fig. 1. Integrated prototype section.

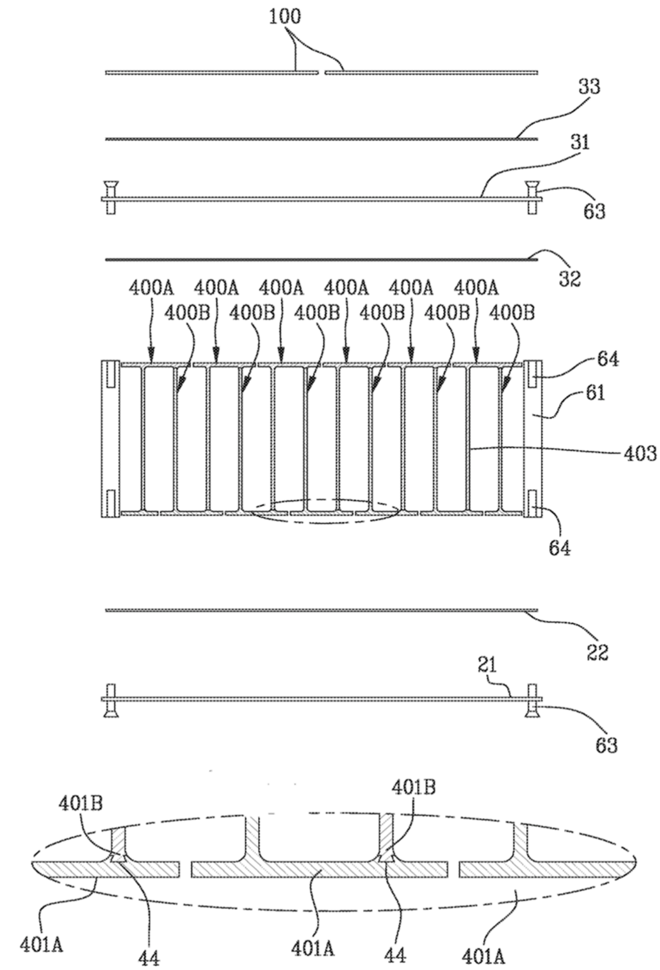

Fig. 2. Integrated TEG apparatus.
(adapted from patent application).

current to flow through. Therefore, the voltages produced by the first element and the second element are algebraically added together. In one (preferred) embodiment, the structure comprises a plurality of first elements and a plurality of second elements, connected in series, to form a series of elements. Each element (first or second) forms one thermocouple with the element (first or second) before it and another thermocouple with the element (first or second) after it in the series of elements. Therefore, each thermocouple is formed by one of the (first or second) elements and by a further element of the (first or second) elements. The voltages produced by the first element and by the second element are algebraically subtracted (since the current flows through them in opposite directions). Preferably, the first value of Seebeck coefficient of the first material is positive and the second value of Seebeck coefficient of the second material is negative (or positive and much lower than the value of the first Seebeck coefficient), or vice versa; in this way, the total voltage, given by the algebraic sum (or by the subtraction) of the voltages produced by the first element and by the second element, will be given by the total of the absolute values of the voltages produced by the first element and by the second element. Therefore, the apparatus allows cooling of the photovoltaic panel and, at the same time, production of a supplementary electric current, which increases the efficiency of conversion of the solar energy into electricity by the system. Indeed, the Seebeck effect occurs inside the same heat exchanger which acts as a support and cooling unit for the photovoltaic cells.

The baseplate includes a base sheet (21) and an electrically insulating base layer (22), applied to an upper face of the base sheet (21).

The insulating base layer (22) is thermally conductive and electrically insulating. In one embodiment, the insulating base layer 22 is made of an elastic material. In this way, the baseplate can disperse heat (so as to cool the structure resting on it) but not conduct electricity. The integrated TEG structure comprises a top plate which includes a top sheet (31). The top plate includes an electrically insulating top layer (32), applied to a lower face of the top sheet 32. The insulating top layer (32) is thermally conductive and electrically insulating. In one embodiment, the insulating top layer 32 is made of an elastic polymeric material. In this way, the top plate can disperse heat (so as to cool the photovoltaic cells) but not conduct electricity. The top plate includes a thermally conductive glue (33) applied to the upper face of the top plate opposite to the lower face. In one embodiment, the thermally conductive glue (33) is electrically insulating. The thermally conductive glue (33) is configured to receive resting on the photovoltaic cells (10) and to stably fasten them to the top sheet (31). The apparatus comprises a structure (also known as the supporting and cooling structure) interposed between the baseplate and the top plate. The structure comprises a frame (6) In one embodiment, the frame (6) includes a pair of lateral uprights (61) fastened to the baseplate and to the top plate. The lateral uprights (61) are fastened on respective opposite sides of the baseplate and of the top plate. In one embodiment, the baseplate and the top plate are rectangular (or square) in shape, that is to say, they have four sides, made up of two opposite pairs. The lateral uprights (61)of the frame are fastened on one pair of opposite sides (preferably the sides elongate parallel to the fins 403A, 403B); cooling fluid (preferably antifreeze liquid such as propylene glycol) input and output connectors are defined on the other pair. Each lateral upright 61 is fastened at a first end to the baseplate and at a second end, opposite the first end, to the top plate. The lateral uprights 61 are fastened to the baseplate and to the top plate by means of a plurality of screws 63. In one embodiment, the baseplate and the top plate include a plurality of screws 63. In one embodiment, defined in the lateral uprights 61 there is a plurality of cavities or internal threads 64, configured to receive the screws 63. In one embodiment, the lateral uprights 61 are elongate parallel to the vertical direction.

3. Background

Among the main renewable energy sources, solar energy has a limited energy density per unit area, making optimisation of energy conversion necessary. Photovoltaic cells, when exposed to solar exposed to solar radiation for a considerable time, can reach very high operating temperatures. This causes:

- reduction in production efficiency
- rapid degradation of the cells themselves

Research activities on integrated systems in recent years have been directed towards the use of thermo-photovoltaic technology in which photovoltaic and solar thermal panels are fused into a single solution, and thermoelectric technology in which systems combined with PV cells PV cells aim to increase their production and provide auxiliary auxiliary power production [2].

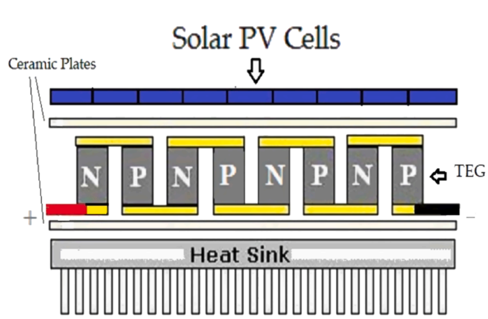

Fig. 3. TEG “State of the art”.

The latter systems (Fig. 3) present certain problems:

- lack of integration
- low energy efficiency
- voluminous and complex structures

The main technical problems to be solved concern the difficulty of assembling and installation of separate cooling systems for photovoltaic cells and thermoelectric conversion, the lack of integration between the thermoelectric system and the heat exchanger in existing cooling systems for solar panels that using the Seebeck-Peltier effect and the low energy efficiency of the overall system.

Alternative solutions [3,4] have separate heat exchangers and thermoelectric generators separate and the heat removed from the photovoltaic cells passes entirely through the thermocouples.

This leads to a reduction in the exchange efficiency (if a high temperature difference between the thermocouples is designed) and a reduction in the Seebeck effect (if a low temperature drop in the thermocouples is designed).

Alternative solutions [5,6] present cooling systems for a photovoltaic panel comprising a plurality of Peltier cells having a first face in contact with contact with the photovoltaic cells and a second face in contact with a heat exchanger heat exchanger (in this case, fins), which exchanges heat with a fluid. Such systems require electrical connections to be made by cable. Furthermore, since they consist of a first layer of Peltier cells and a second layer of cooling fins. cooling fins, they entail high costs, weight and space requirements. These problems are solved by the invention within a simplified and modular for the needs of different customers.

The invention addresses the problems described above through these solutions:

- increasing the combined efficiency of photovoltaic and thermoelectric production
- achievement of greater compactness and robustness compared to complex existing solutions with very small overall dimensions.

For a standard photovoltaic panel of 100 x 125 cm (from 7 to 9 modules) the proposed cooling system allows an increase of almost 15% of the electrical power converted by the cells. Moreover, the exploited Seebeck effect provides an electrical power that is respectively 10.9 and 4 times higher (for the inorganic materials analyzed) than the power required for system forced ventilation. The maximum electrical power reachable for the system size adopted, considering all electrical power gains and losses is near to 300–310 W/m^2.

4. Application potential

The end users targeted by this solution (private individuals, companies, public administration,…) are those who wish to optimise the photovoltaic production of their plant and at the same time obtain auxiliary electricity production using an efficient system with a small footprint.

Ethics statements

No specific ethics statement.

CRediT authorship contribution statement

Matteo Greppi: Conceptualization, Methodology, Data curation, Writing – review & editing, Writing – original draft, Visualization, Investigation. **Giampietro Fabbri:** Conceptualization, Supervision, Validation, Writing – review & editing, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.inv.2023.100019.

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