



СТАНОВИЩЕ

ОТНОСНО: Проучване за новост на „Синергична фотоволтаична система с подвижни двустранни плоски светлинни отразители с циклично охлаждане от естествена атмосферна вода“, Вх. № СпИС -707/20.06.2022

Към искането за проучване са приложени описание, чертежи и претенции.

Формулирани са една независима и десет зависими претенции.

Синергичната фотоволтаична система с подвижни двустранни плоски светлинни отразители с циклично охлаждане от естествена атмосферна вода, съгласно независимата претенция 1, включва фотоволтаичен панел представляващ паралелепипедна кутия, към задната повърхнина на който е монтиран влагоабсорбатор за събиране на атмосферна вода, а към горната и долната хоризонтални стени на фотоволтаичния панел на съответно горен и долен хоризонтални валове са фиксирани горен и долен отразителни капаци с възможност за завъртане от горен и долен задвижващи механизми, монтирани съответно към горния и долния хоризонтални валове. За задвижването на отразителните капаци в съответствие с данни от комбиниран датчик за положението на слънцето и климатични параметри, комбиниран датчик за температурата на предната повърхност на фотоволтаичния панел и електрическите параметри на генерацията от фотоволтаичния панел е предвиден оптимизиращ управленски блок.

При извършеното проучване се установи наличие на известни от предшестващото състояние на техниката документи, отразяващи нивото на техниката, които са посочени в приложения доклад от проучване и които не са противопоставими по новост на обекта на проучване, а именно:

KR101032515 (B1) /2011-05-04, където е разкрит слънчев панел с форма на паралелепипед, оборудван с фотоволтаични клетки за генериране на електродвижеща сила, използваща слънчева светлина; отразяващи плочи, монтирани с възможност за въртене от горната и долната хоризонтални страни на слънчевия панел, за да отразява слънчевата светлина върху цялата повърхност на слънчевия панел; задвижващо устройство за завъртане на отразяващите плочи по отношение на слънчевия панел; отразяващите плочи имат същия размер като зоната за приемане на светлина на слънчевия панел; върху задната повърхнина на слънчевия панел е монтиран радиатор с тръба за охлаждаща вода, вградена в жлеб, изработен върху повърхността на радиатора и с капак, прикрепен към повърхността на радиатора, за да покрие тръбата за вода. Блокът за управление на слънчевия панел включва управление на задвижващите механизми за завъртане под определен ъгъл на отразяващите плочи при отчитане на позицията на слънцето и инжектиране на охлаждаща вода в радиатора при повишаване температурата на слънчевия панел.

BG111244 (A)/ 2013-12-31, където е разкрито охлаждане на слънчев панел с форма на паралелепипед чрез изпаряване на влага, осигурена от плътна мрежа капилярни влакна, прикрепени към задната повърхност на панела. Водата се подава към мрежата от капилярни влакна или чрез система за капково напояване, монтирана в горния край на фотоволтаичния модул или чрез потапяне на краищата им в подходящ воден резервоар. Алтернативно, водоснабдяването на мрежата от капилярни влакна се осигурява от диспергиращи дюзи разположени зад фотоволтаичния модул. Те се включват периодически за кратко време с цел напояване на мрежата от капилярни влакна и нагрятата задна повърхност на модулите. Това действие се управлява автоматично от компютризиран модул.



ПАТЕНТНО ВЕДОМСТВО НА РЕПУБЛИКА БЪЛГАРИЯ

US2009151769A1/ 2009-06-18, където е разкрит слънчев фотоволтаичен панел, за който са осигурени апарат, система и метод за оптимизиране на извличането на енергия от масив от слънчеви клетки и защита на масива от слънчеви клетки от атмосферни условия, включително преместване на рефлекторни панели до предварително определена ъглова позиция на базата на условията на околната среда, или други фактор.

В нито един от намерените при проучването документи не е разкрито техническо решение, което да съдържа всички признаци на обекта на проучването от претенция 1.

Експертизата счита, че обектът на проучването с обхват от претенция 1 отговаря на изискванията за новост, съгласно чл. 8 от ЗПРПМ.

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Maya Angelova
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Държавен експерт ДЕЗИПД



ПАТЕНТНО ВЕДОМСТВО НА РЕПУБЛИКА БЪЛГАРИЯ

ДОКЛАД ОТ ПРОУЧВАНЕ		
Прочване за новост на „Синергична фотоволтаична система с подвижни двустранни плоски светлинни отразители с циклично охлаждане от естествена атмосферна вода“		
Вх. № СпИС -707/20.06.2022		
I. Уточнен класификационен индекс по МПК		
H02S		
II. ОБЛАСТ НА ПРОУЧВАНЕ:		
Минимален обхват на прочване		
Вид класификация:	Класификационен индекс:	
МПК	H02S	
Бази данни, в които е извършено прочването		
Esp@cenet; IPAS; epoquenet		
III. Релевантни документи		
Категория	Цитиране на документите с посочване на релевантните части	Релевантни претенции
A	KR101032515 (B1) /2011-05-04 LEE BUM-SU [KR] ; GWON YWON-HUI [KR]	1-11
A	BG111244 (A)/ 2013-12-31 MITEV GANCHO [BG]	1-11
A	US2009151769A1/ 2009-06-18 CORBIN JOHN C [US]	1-11
Категория на документа		
X – документът е от особено значение; претендираното изобретение няма новост или изобретателска стъпка, когато документът се разглежда самостоятелно		
Y – документът е от особено значение; претендираното изобретение няма изобретателска стъпка, когато документът се комбинира с един или повече други документи и тази комбинация е очевидна за специалист в областта		
A – документ, отразяващ нивото на техниката, който не е от особено значение		
Дата: 01.09.2022	Експерт Име: Мая Тодорова	Maya Angelova Todorova Държавен експерт ДЕЗИПМПД

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Date: 2022.09.01
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Bibliographic data: KR101032515 (B1) — 2011-05-04

PHOTOVOLTAIC APPARATUS COMPRISING ANGLE-ADJUSTABLE REFLECTING PLATE

Page bookmark [KR101032515 \(B1\) - PHOTOVOLTAIC APPARATUS COMPRISING ANGLE-ADJUSTABLE REFLECTING PLATE](#)

Inventor(s): LEE BUM SU [KR]; GWON YEON HUI [KR] [+](#)

Applicant(s): GWON YEON HUI [KR]; LEE BUM SU [KR] [+](#)

Classification:
- international: [H01L31/052](#)
- cooperative: [H01L31/0547 \(EP\)](#); [H02S40/22 \(KR\)](#); [H02S40/425 \(KR\)](#); [Y02B10/10 \(EP\)](#); [Y02E10/50 \(KR\)](#); [Y02E10/52 \(EP\)](#)

Application number: KR20110015812 20110223 [Global Dossier](#)

Priority number(s): KR20110015812 20110223

Also published as: [WO2012115378 \(A2\)](#) [WO2012115378 \(A3\)](#)

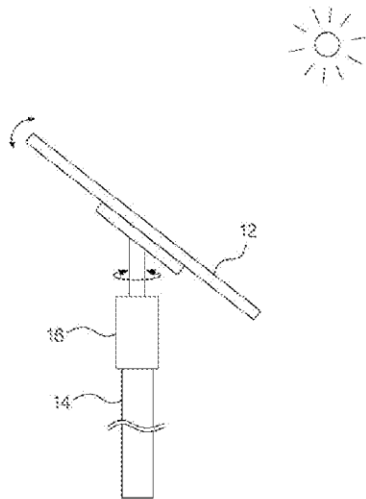
Abstract of KR101032515 (B1)

PURPOSE: A solar light power generating device with a reflective plate is provided to use solar light which is directly incident on a solar battery plate as well as other solar light, thereby increasing the electricity power generating amount of the solar battery plate. **CONSTITUTION:** A solar battery plate(110) generates electromotive power using solar light. A first reflection plate(121) and a second reflection plate(122) are coupled with the upper and lower ends of the solar battery plate. The first reflection plate is coupled with the upper end of the solar battery plate using a first hinge(131). The second reflection plate is coupled with the lower end of the solar battery plate using a second hinge(132). The first and second reflection plates have the same size as the size of a corresponding light receiving area of each solar battery plate.

도면

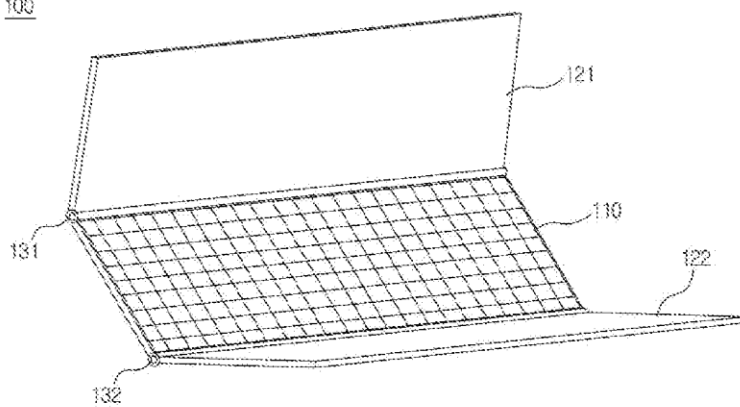
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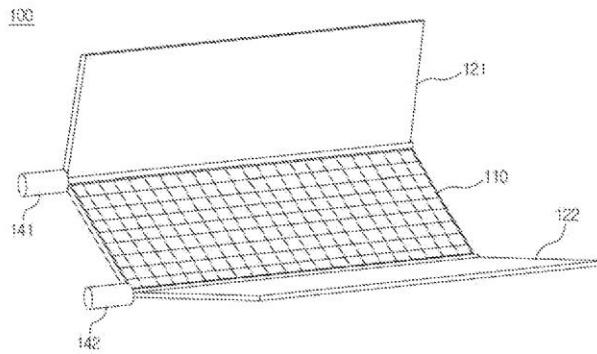


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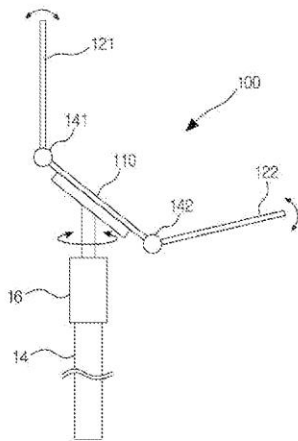
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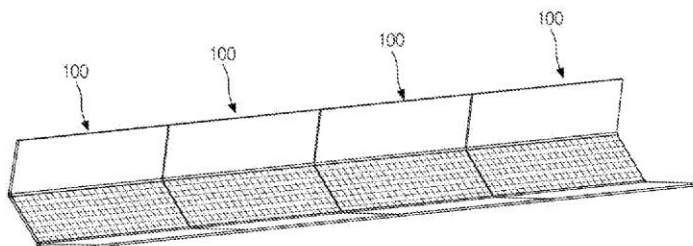
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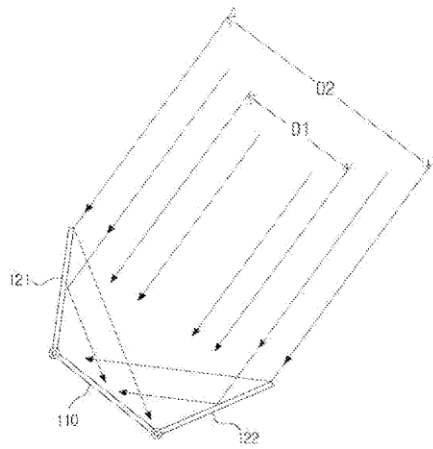
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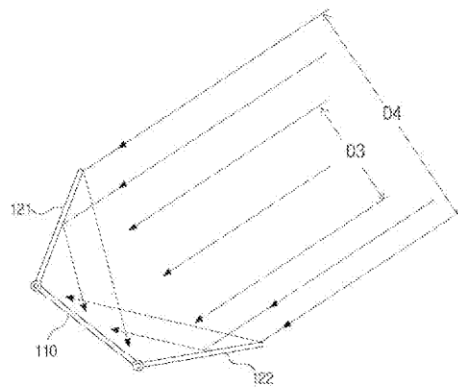
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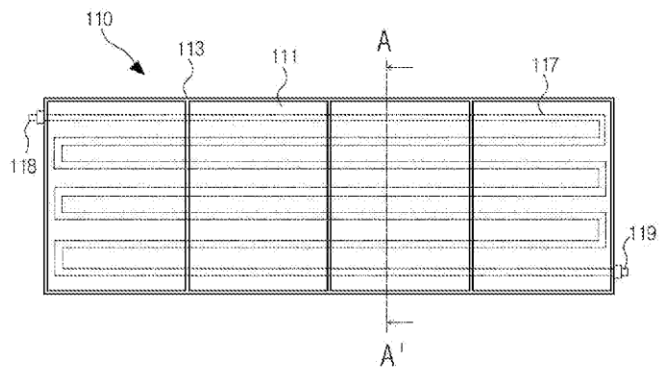
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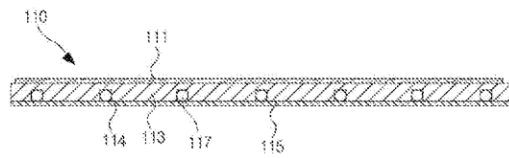
도면7



도면8



도면9



Bibliographic data: BG111244 (A) — 2013-12-31

SYSTEMS AND METHODS TO INCREASE THE EFFICIENCY OF PHOTOVOLTAIC SYSTEMS BY CONTROLLING THE OPERATING TEMPERATURE OF THE MODULES

Page bookmark [BG111244 \(A\) - SYSTEMS AND METHODS TO INCREASE THE EFFICIENCY OF PHOTOVOLTAIC SYSTEMS BY CONTROLLING THE OPERATING TEMPERATURE OF THE MODULES](#)

Inventor(s): MITEV GANCHO [BG] [+](#)

Applicant(s): MITEV GANCHO [BG] [+](#)

Classification:
- international: [H01L31/052](#)
- cooperative: [F24S10/00 \(GB\)](#); [H01L31/0521 \(EP, GB\)](#); [Y02B10/20 \(EP\)](#); [Y02E10/44 \(EP\)](#); [Y02E10/50 \(EP\)](#)

Application number: BG20120111244 20120622

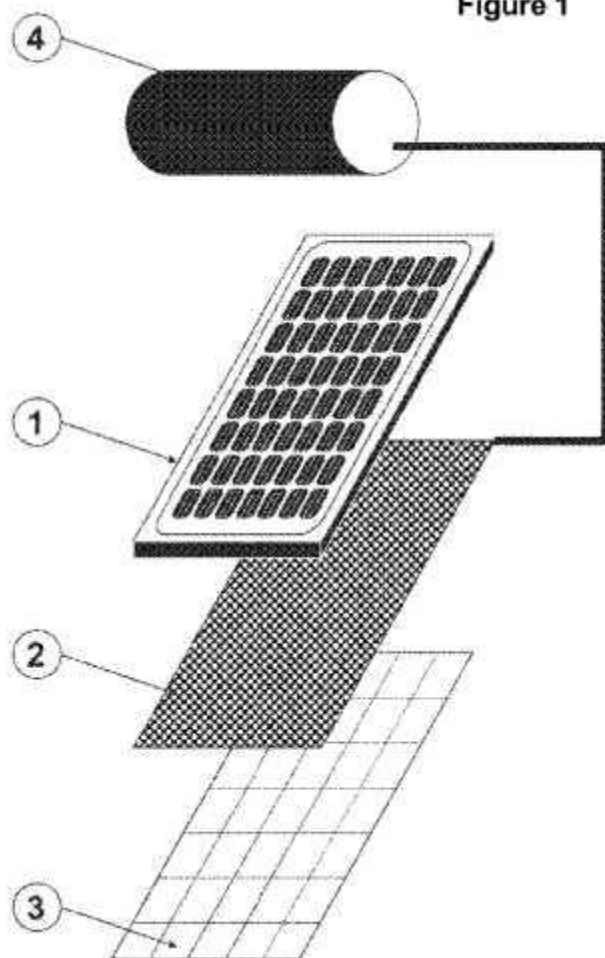
Priority number(s): BG20120111244 20120622

Also published as: [GB2504802 \(A\)](#)

Abstract of BG111244 (A)

The invention relates to the area of photovoltaic (PV) systems for direct conversion of solar energy into electricity. The invention represents a combination of current state of the components, increasing the efficiency of the photovoltaic systems by controlling the operating temperature of the modules (1). By evenly humidification of the heated back surface of the photovoltaic modules (1) is achieved their constant cooling for the conveyance and distribution of humidity are used capillary fiber bundles (2). They are pressed to the surface of the module (1) of the network (3). The capillary effect provides a continuous, evenly distributed humidity over the surface of the modules (1). Humidification of capillary fibers (2) is provided by a drip irrigation system with a reservoir (4), as periodically water is added in necessary amount to achieve a constant operating temperature of the photovoltaic modules (1).

Figure 1



Bibliographic data: US2009151769 (A1) — 2009-06-18

DEVICE AND SYSTEM FOR IMPROVED SOLAR CELL ENERGY COLLECTION AND SOLAR CELL PROTECTION

Page bookmark [US2009151769 \(A1\) - DEVICE AND SYSTEM FOR IMPROVED SOLAR CELL ENERGY COLLECTION AND SOLAR CELL PROTECTION](#)

Inventor(s): CORBIN JOHN C [US] [±](#)

Applicant(s):

-
international: [H01L31/052](#)

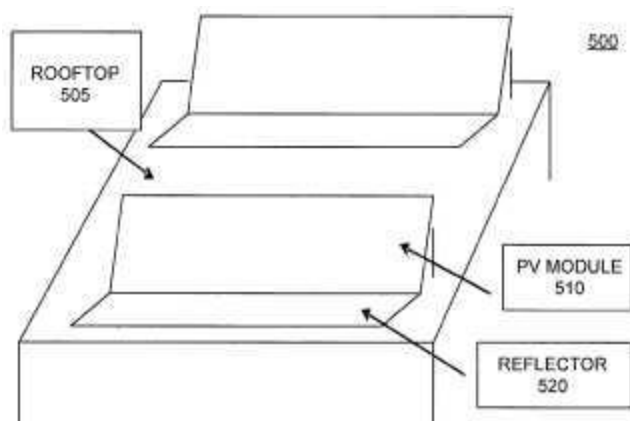
Classification: [F24S23/77 \(EP, US\)](#); [F24S30/425 \(EP, US\)](#); [F24S40/10 \(EP, US\)](#);
[F24S40/40 \(EP, US\)](#); [F24S50/00 \(EP, US\)](#); [F24S50/20 \(EP, US\)](#);
- cooperative: [H01L31/0547 \(EP, US\)](#); [H02S20/23 \(EP, US\)](#); [H02S40/22 \(EP, US\)](#);
[Y02B10/10 \(EP, US\)](#); [Y02E10/47 \(EP, US\)](#); [Y02E10/52 \(EP, US\)](#)

Application number: US20080330262 20081208 [Global Dossier](#)

Priority number(s): US20080330262 20081208 ; [US20070006004P 20071214](#)

Also published as: [WO2009079261 \(A2\)](#) [WO2009079261 \(A3\)](#)

Abstract of US2009151769 (A1)



An apparatus, system and method are provided for optimizing energy retrieval from an array of solar cells and protecting the array of solar cells from weather-related conditions, including moving a reflector panel to a predetermined angular position on the basis of an ambient condition, or some other factor.

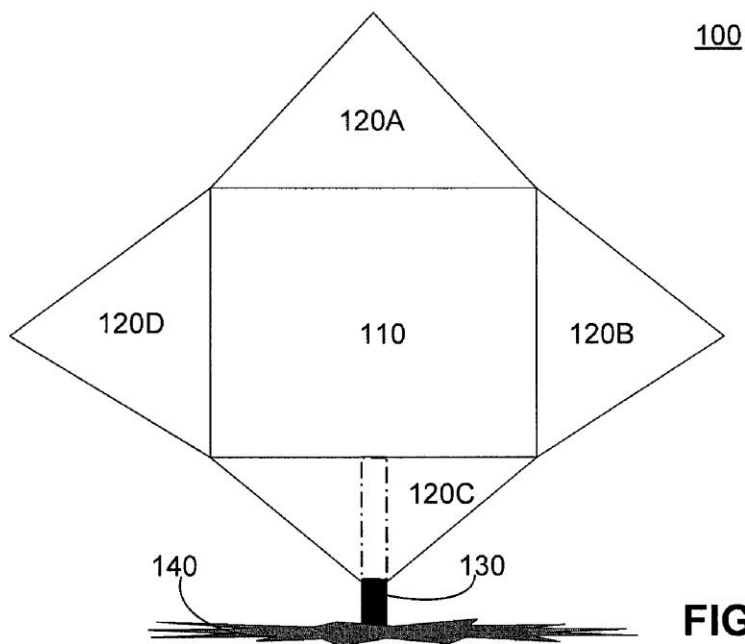


FIG. 1A

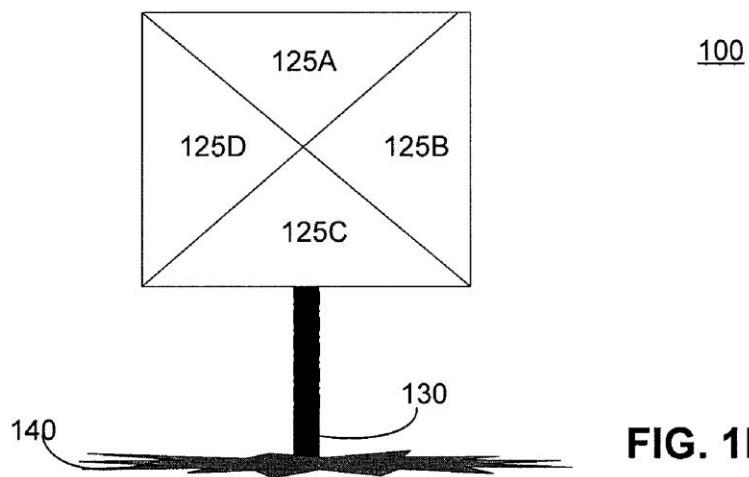


FIG. 1B

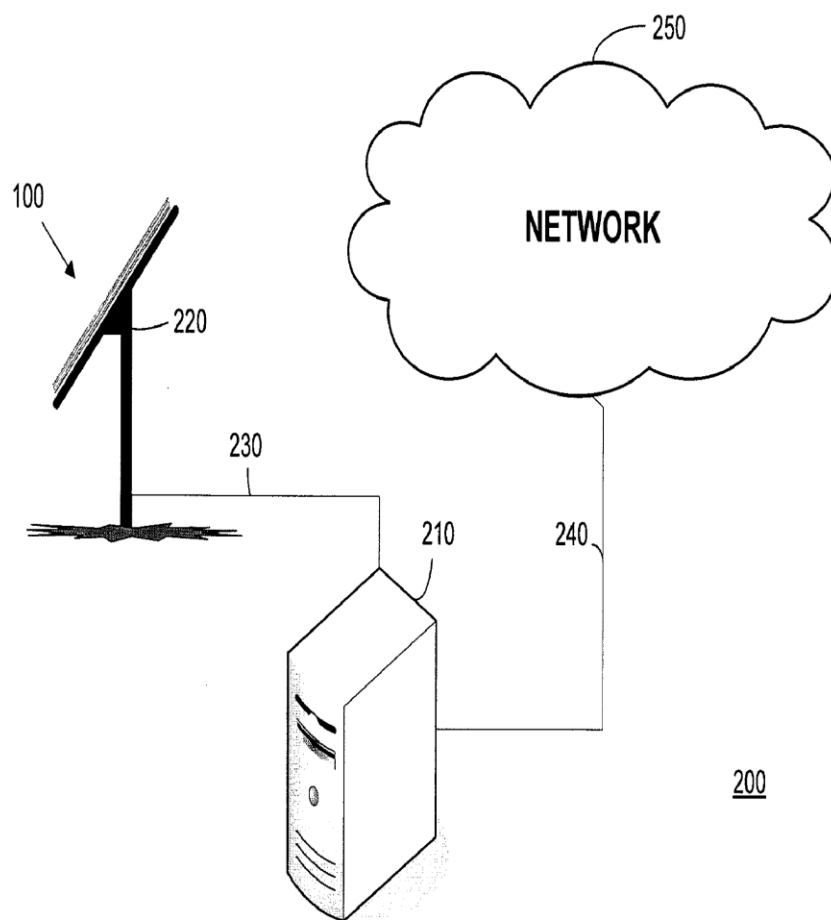
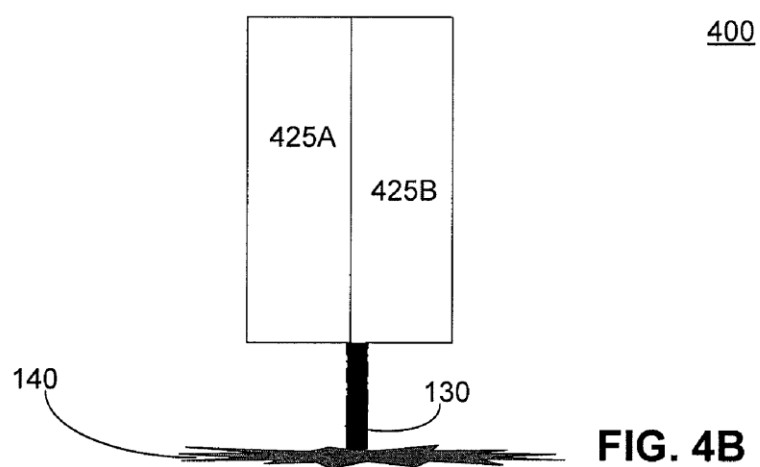
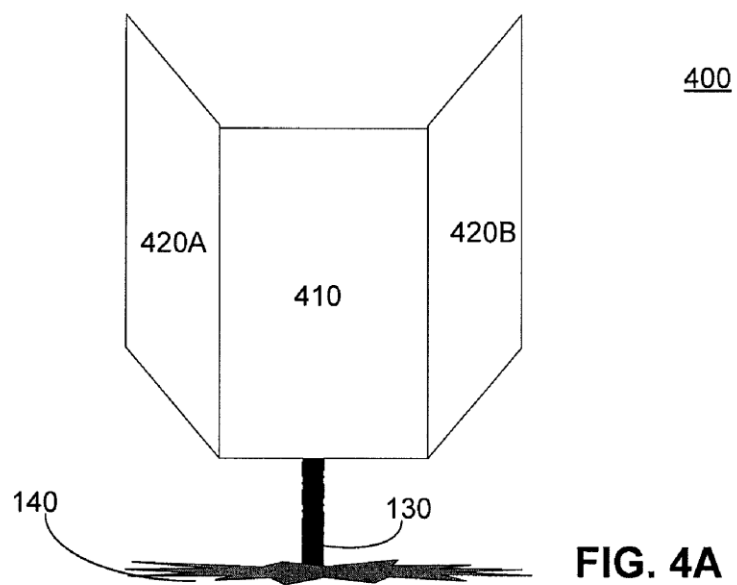
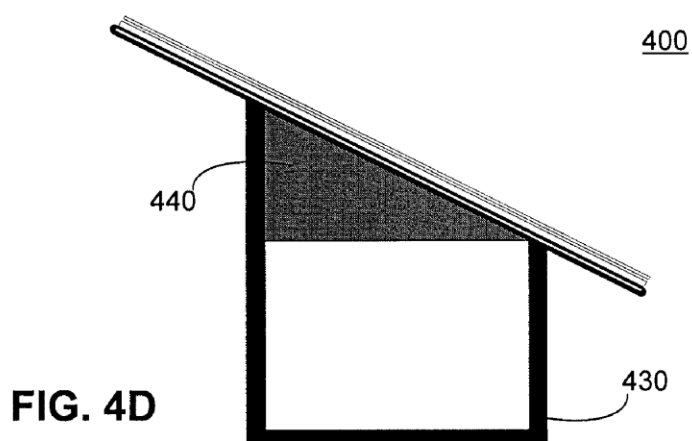
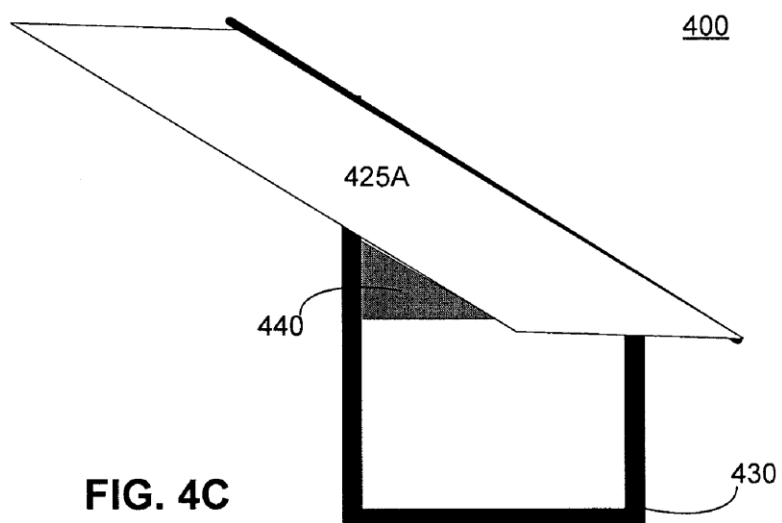


FIG. 2





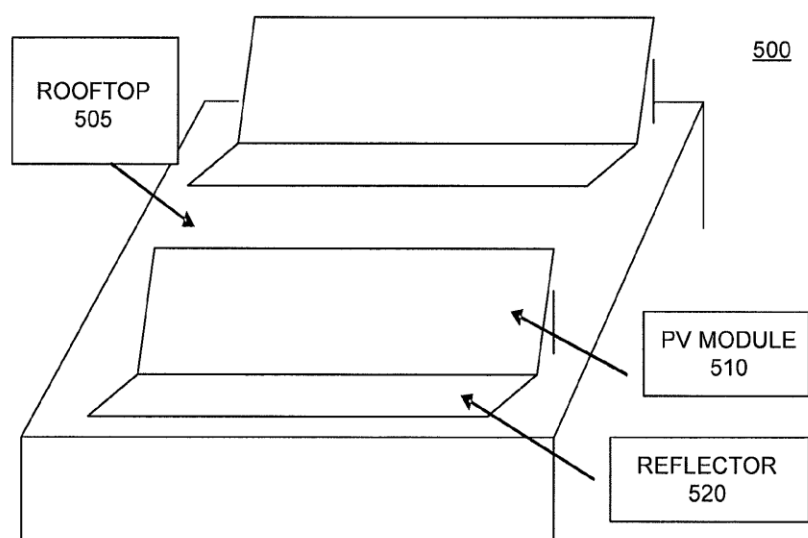


FIG. 5A

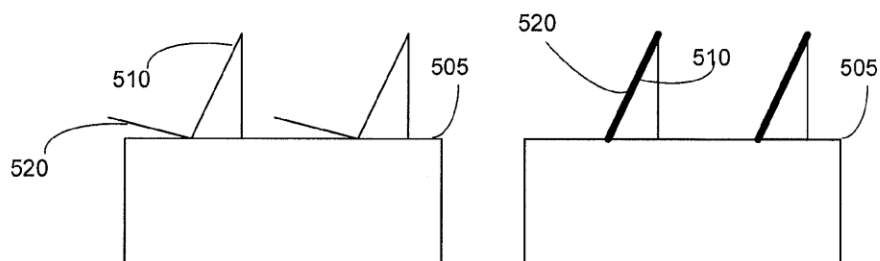


FIG. 5B

FIG. 5C



US 20150185741A1

(19) **United States**(12) **Patent Application Publication**
Rangarajan et al.(10) **Pub. No.: US 2015/0185741 A1**(43) **Pub. Date: Jul. 2, 2015**(54) **FUZZY LOGIC CONTROL OF
THERMOELECTRIC COOLING IN A
PROCESSOR****Publication Classification**

(51) **Int. Cl.**
G05D 23/19 (2006.01)
G06N 5/04 (2006.01)
G05B 15/02 (2006.01)

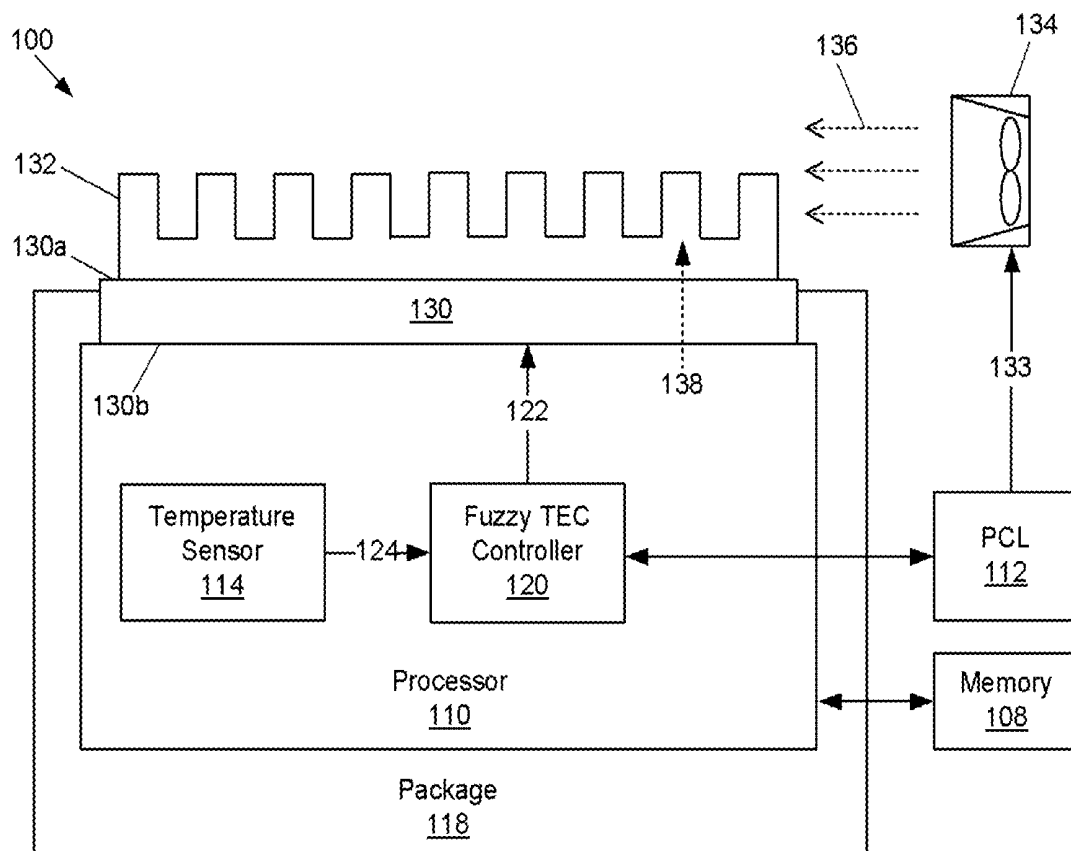
(52) **U.S. Cl.**
CPC **G05D 23/19** (2013.01); **G05B 15/02**
(2013.01); **G06N 5/048** (2013.01)

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Plains, OR (US)(21) Appl. No.: **14/548,361**(22) Filed: **Nov. 20, 2014**(30) **Foreign Application Priority Data**

Dec. 30, 2013 (IN) 6174/CHE/2013

(57) **ABSTRACT**

In an embodiment, a processor includes a fuzzy thermoelectric cooling (TEC) controller to: obtain a current TEC level associated with the processor; obtain a current fan power level associated with the processor; fuzzify the current TEC level to obtain a first fuzzy fan level; fuzzify the current fan power level to obtain a second fuzzy fan level; determine a new TEC power level based at least in part on the first fuzzy fan level, the second fuzzy fan level, and a plurality of fuzzy rules; and provide the new TEC power level to a TEC device associated with the processor, where the TEC device is to transfer heat from the processor to a heat sink. Other embodiments are described and claimed.



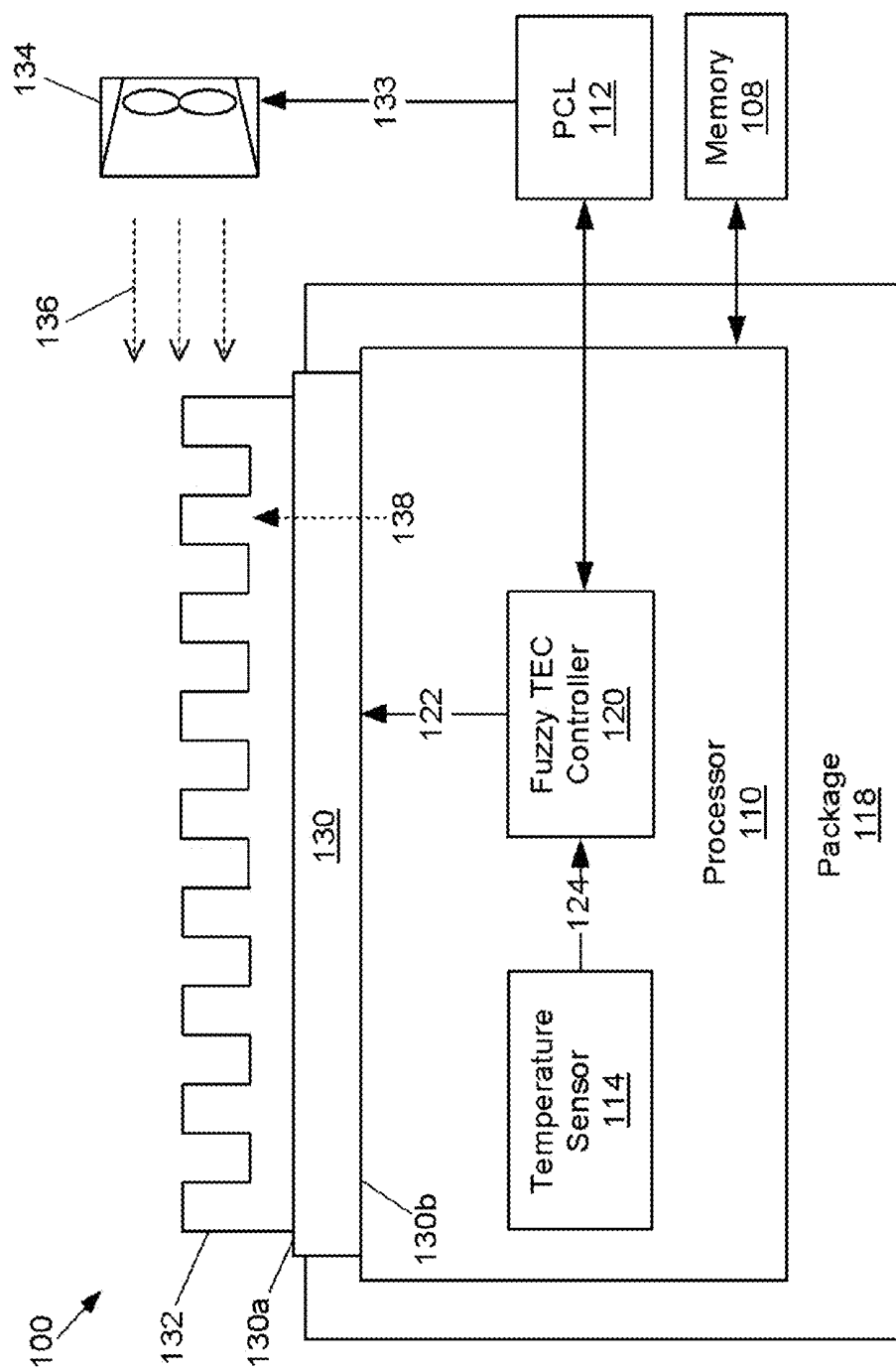


FIG. 1A

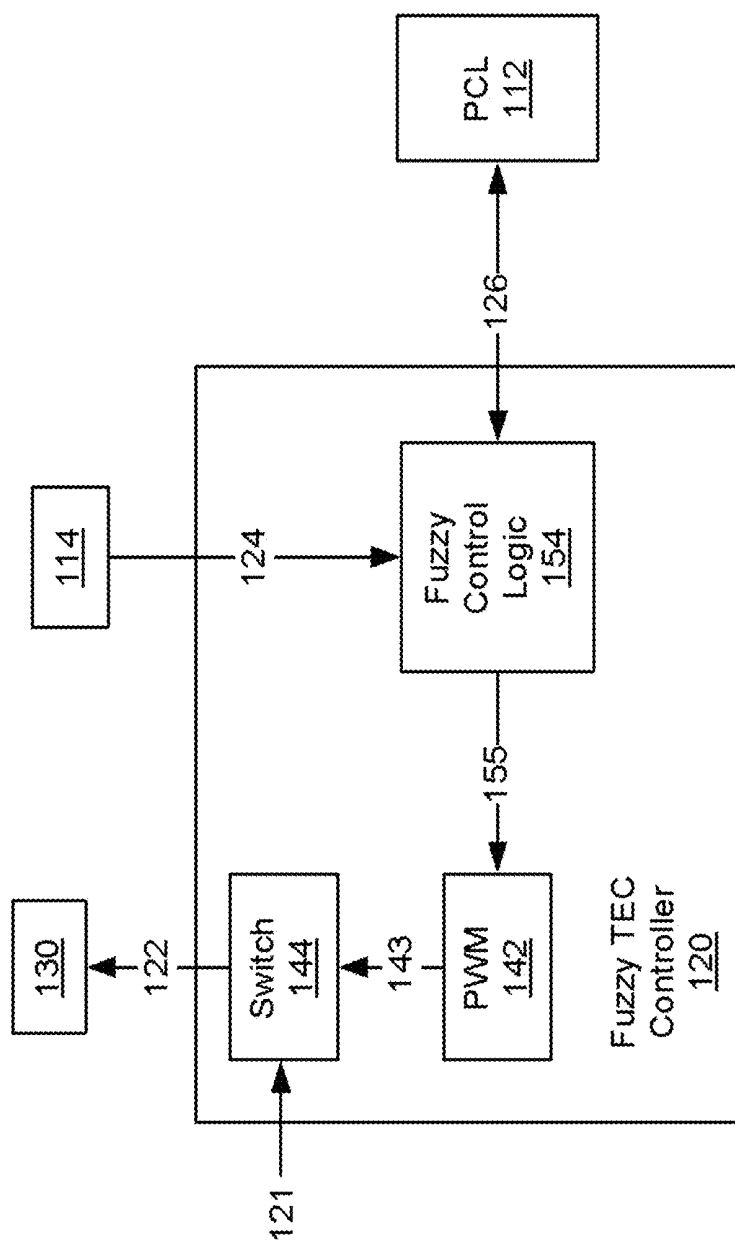


FIG. 1B

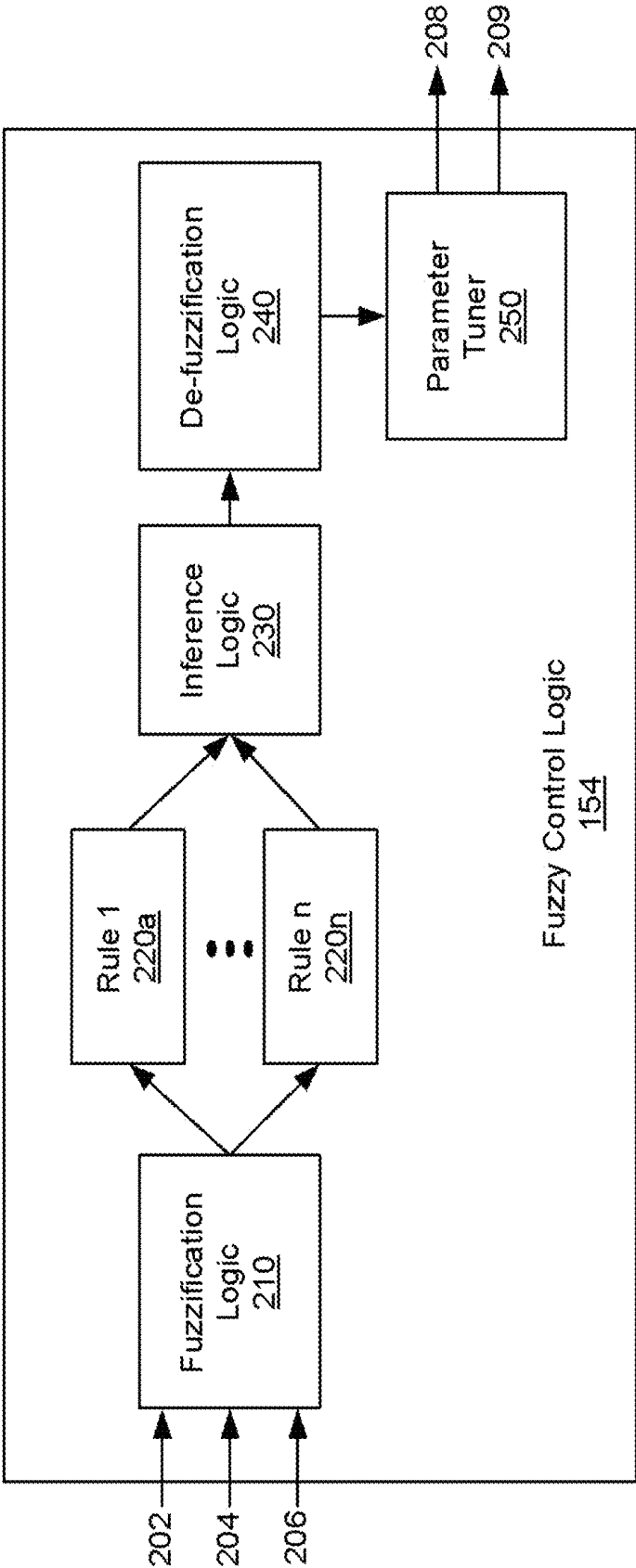


FIG. 2A

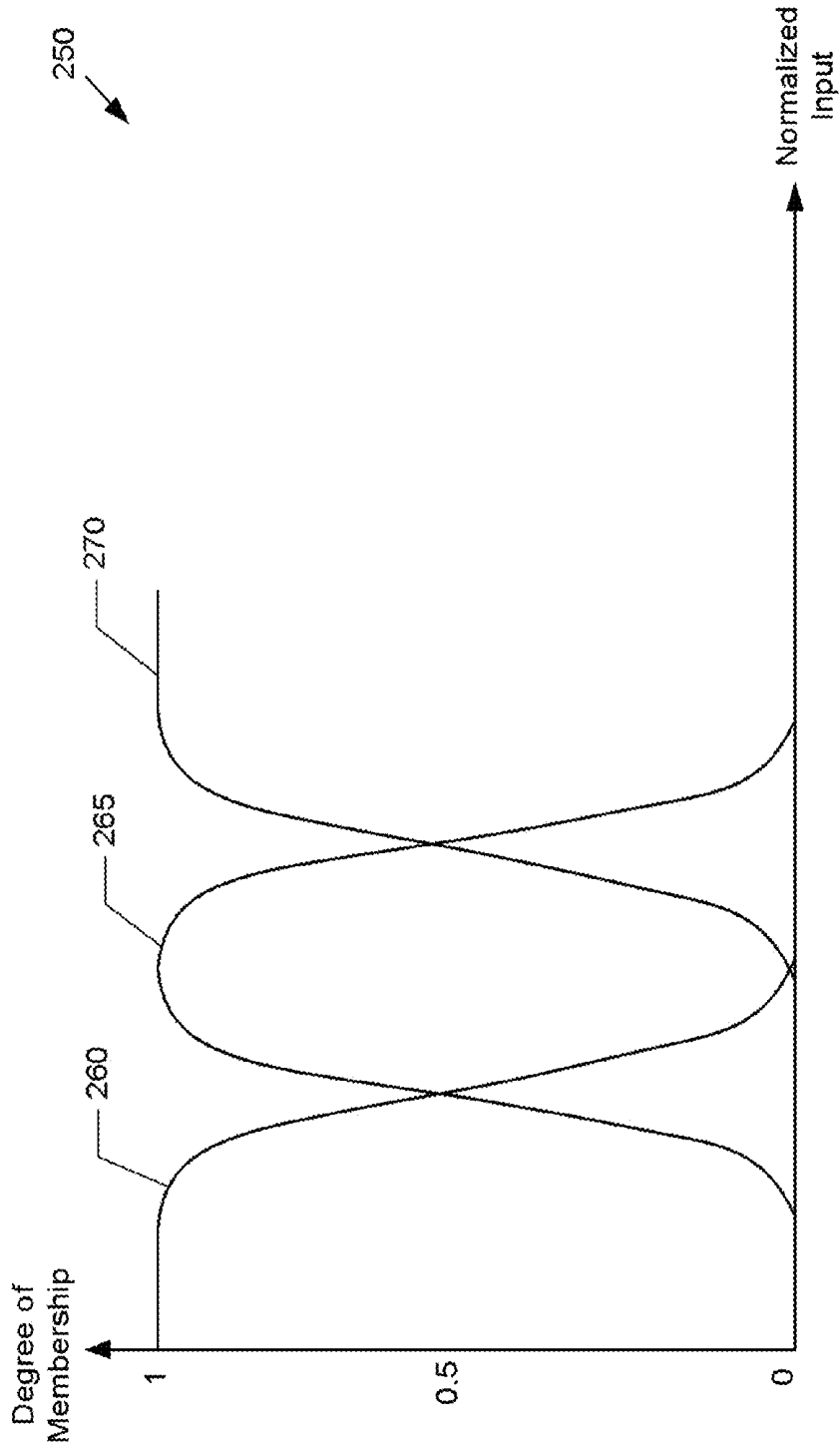


FIG. 2B

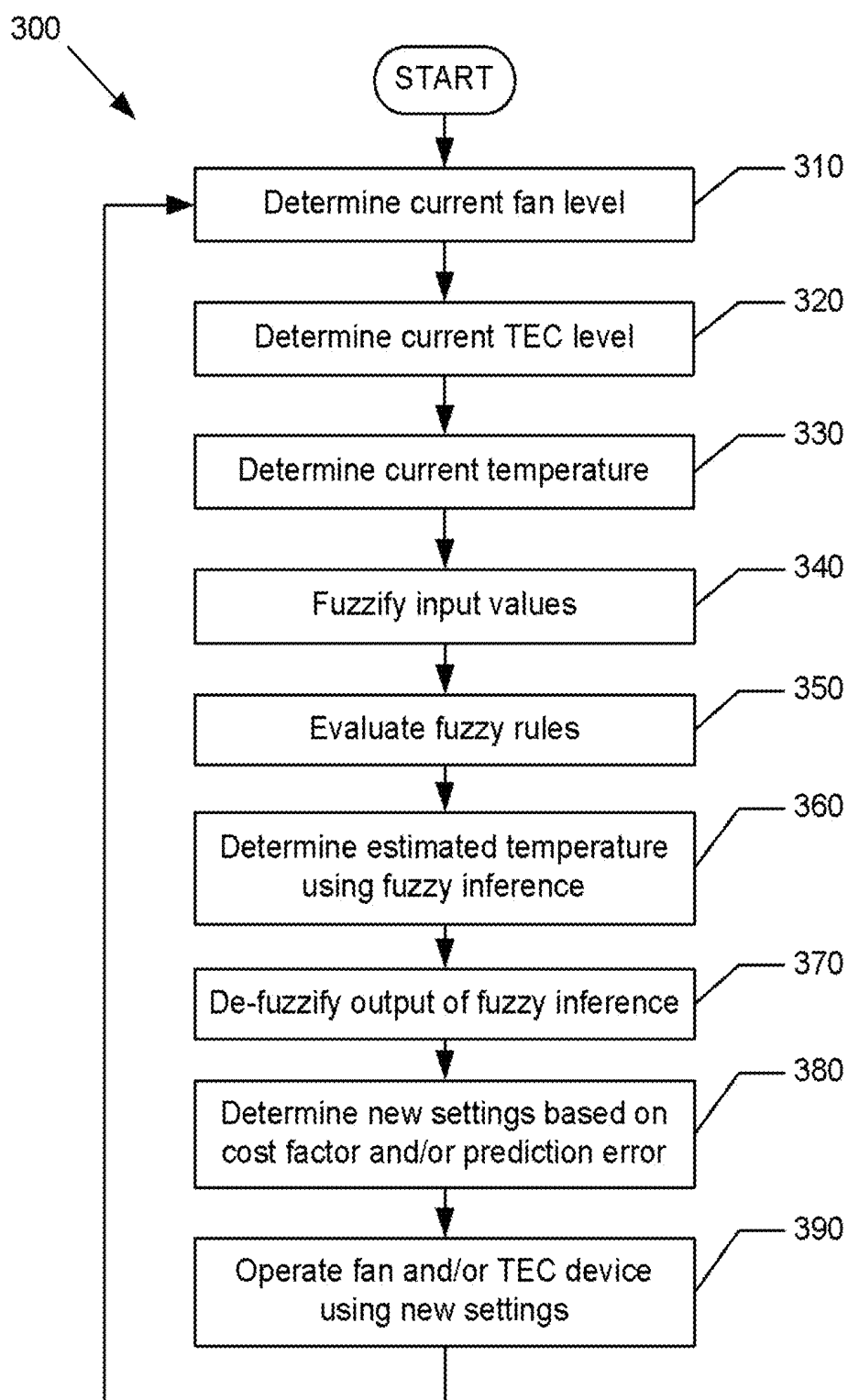


FIG. 3

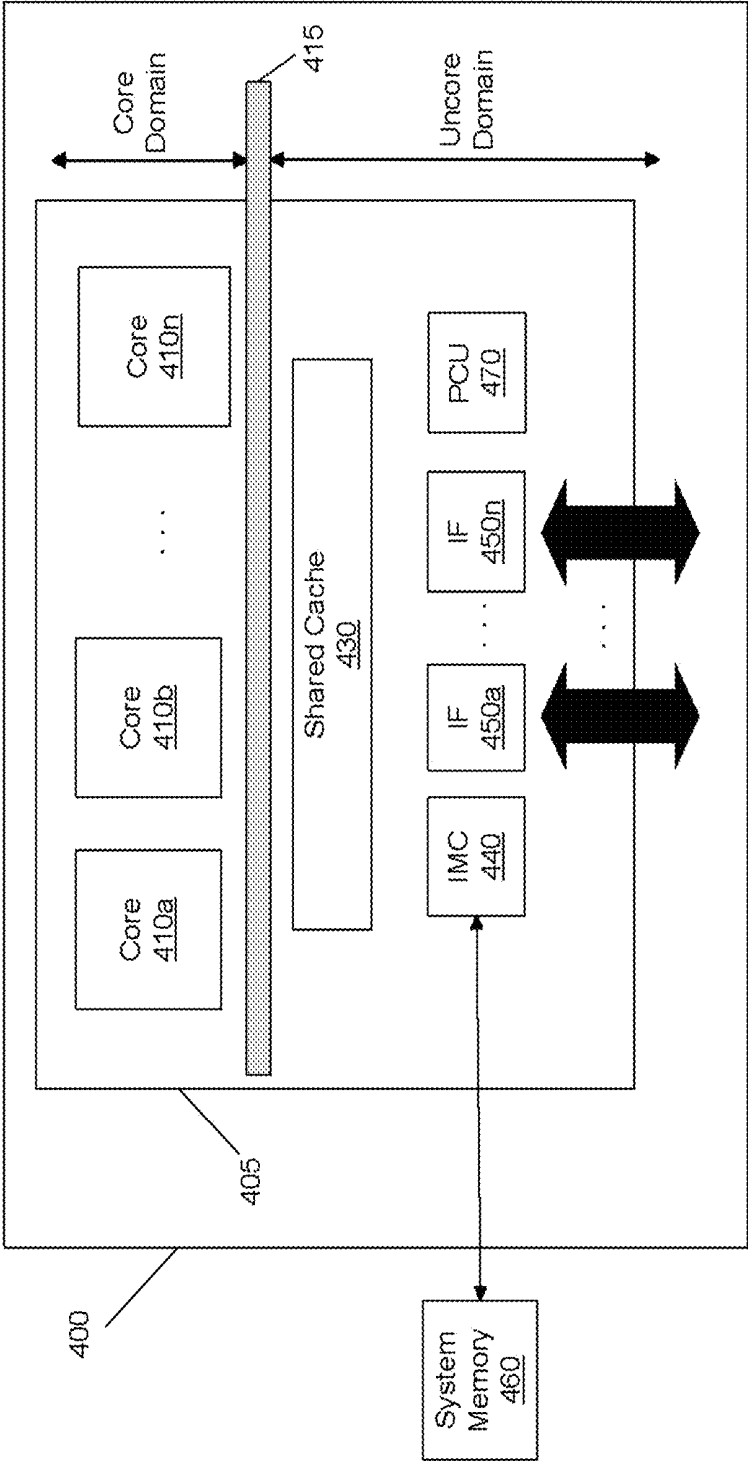


FIG. 4

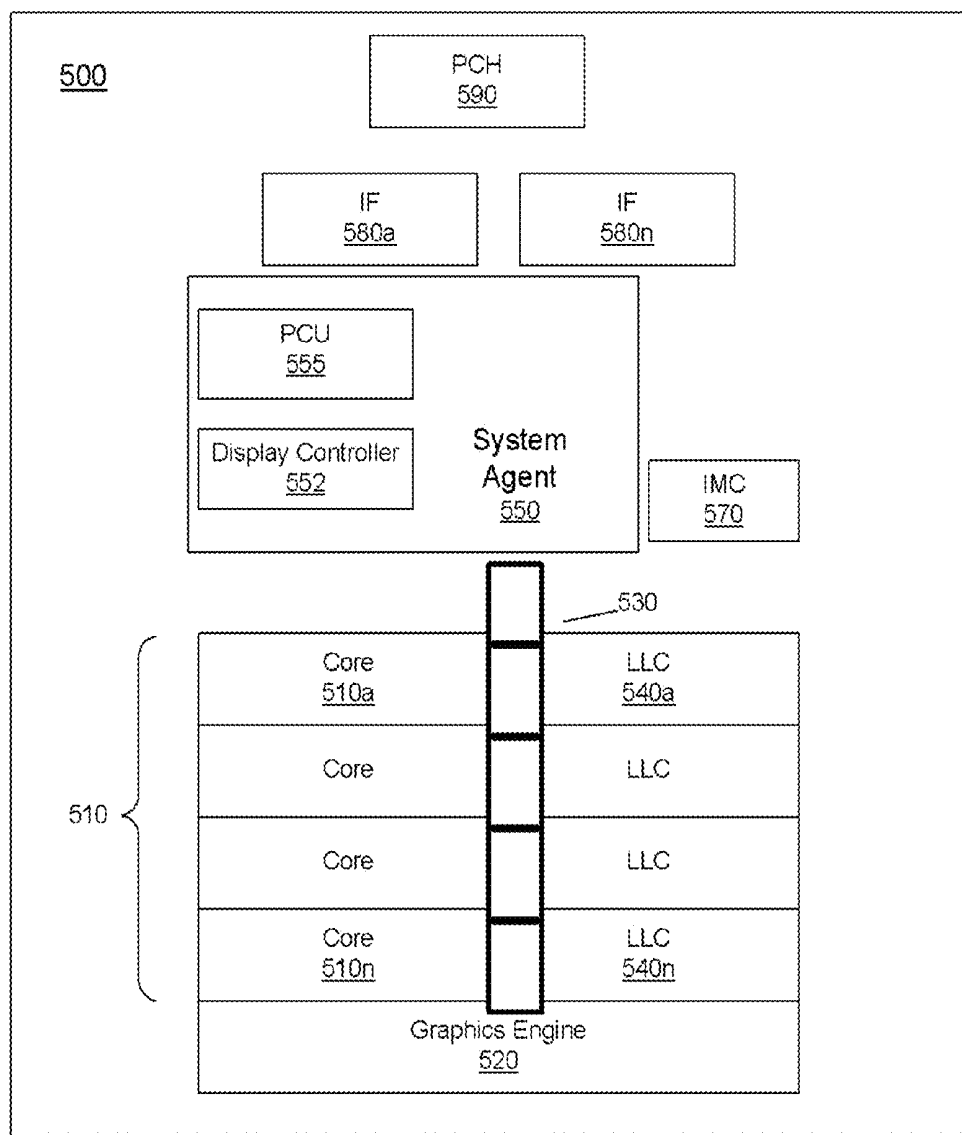


FIG. 5

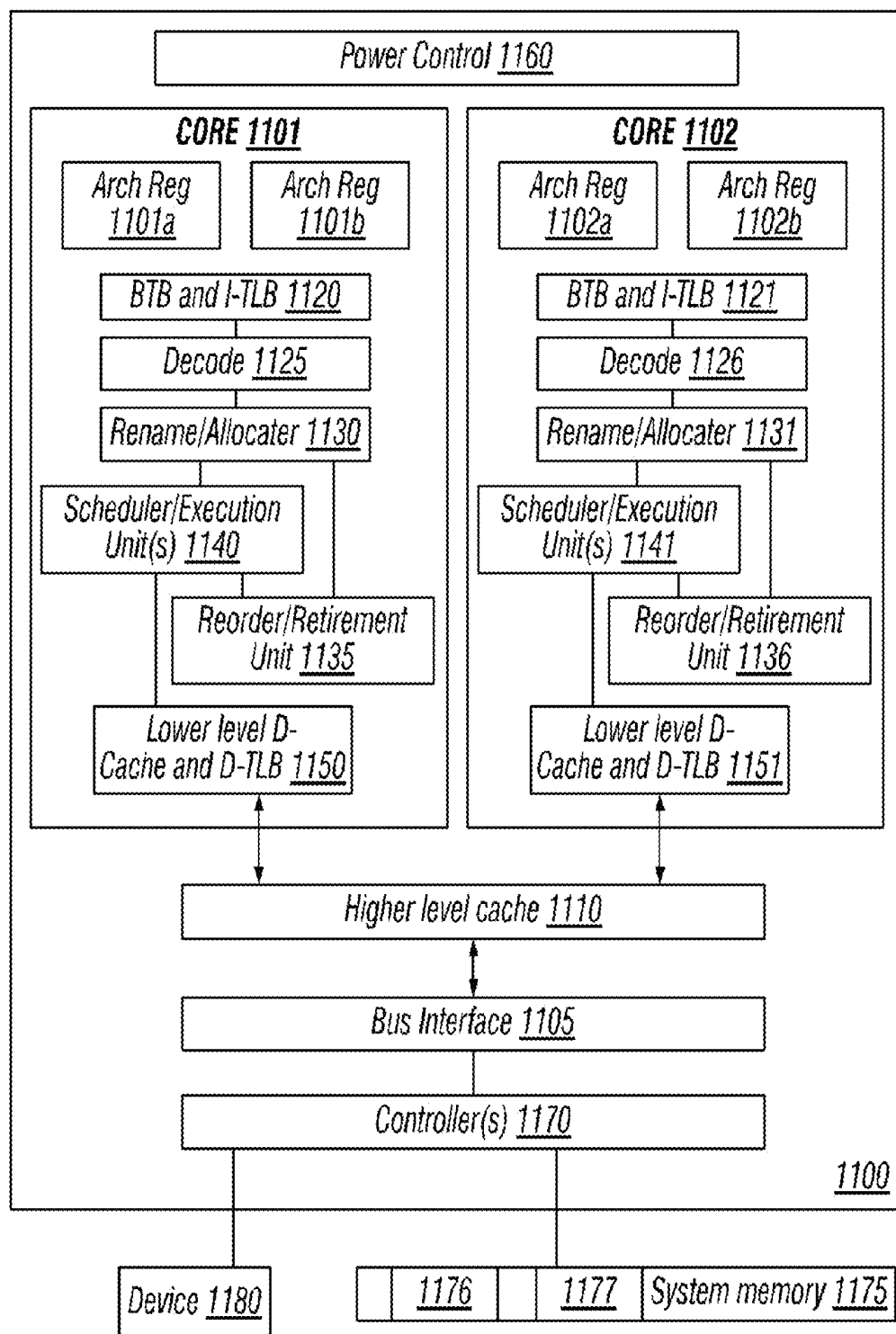


FIG. 6

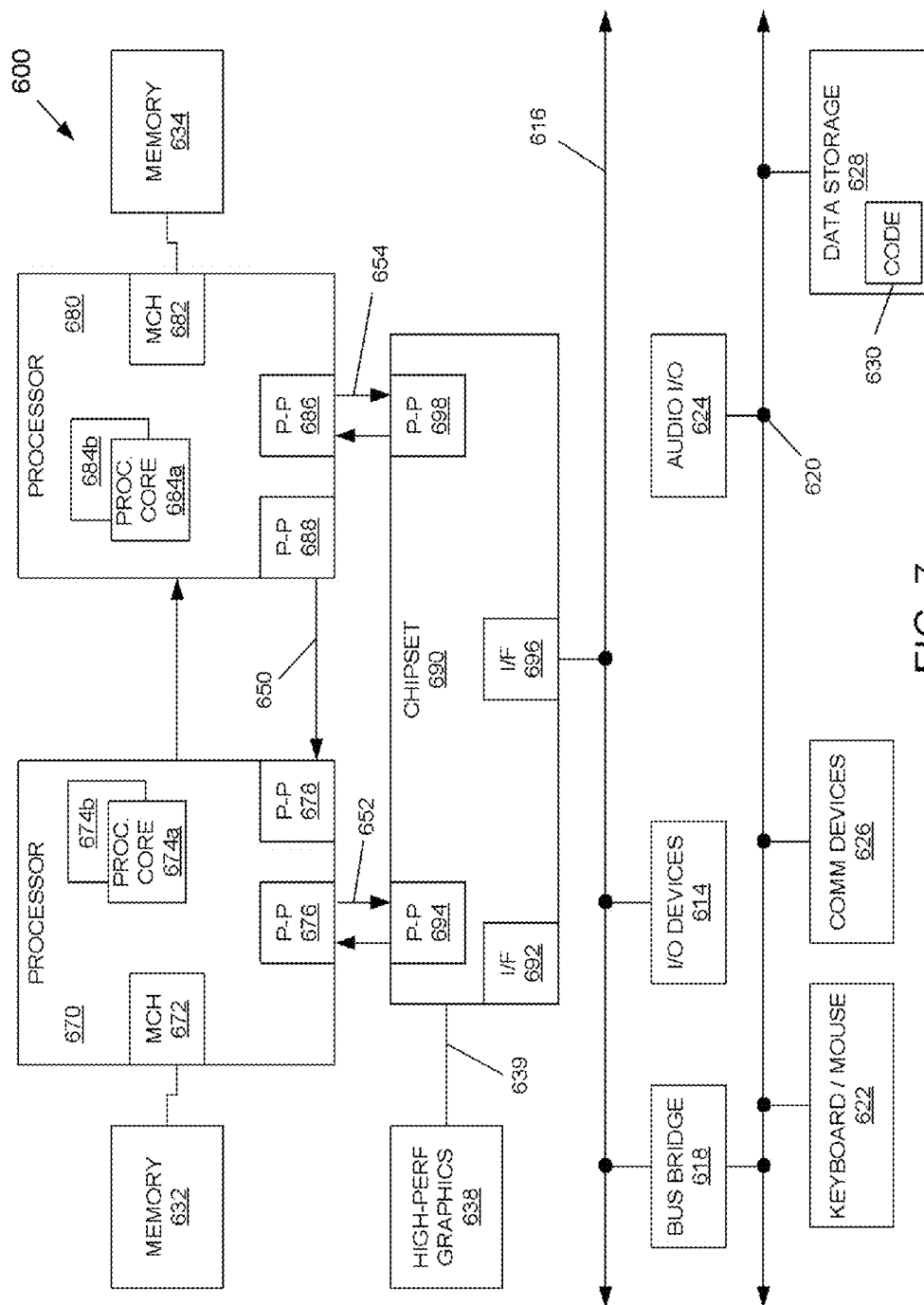


FIG. 7

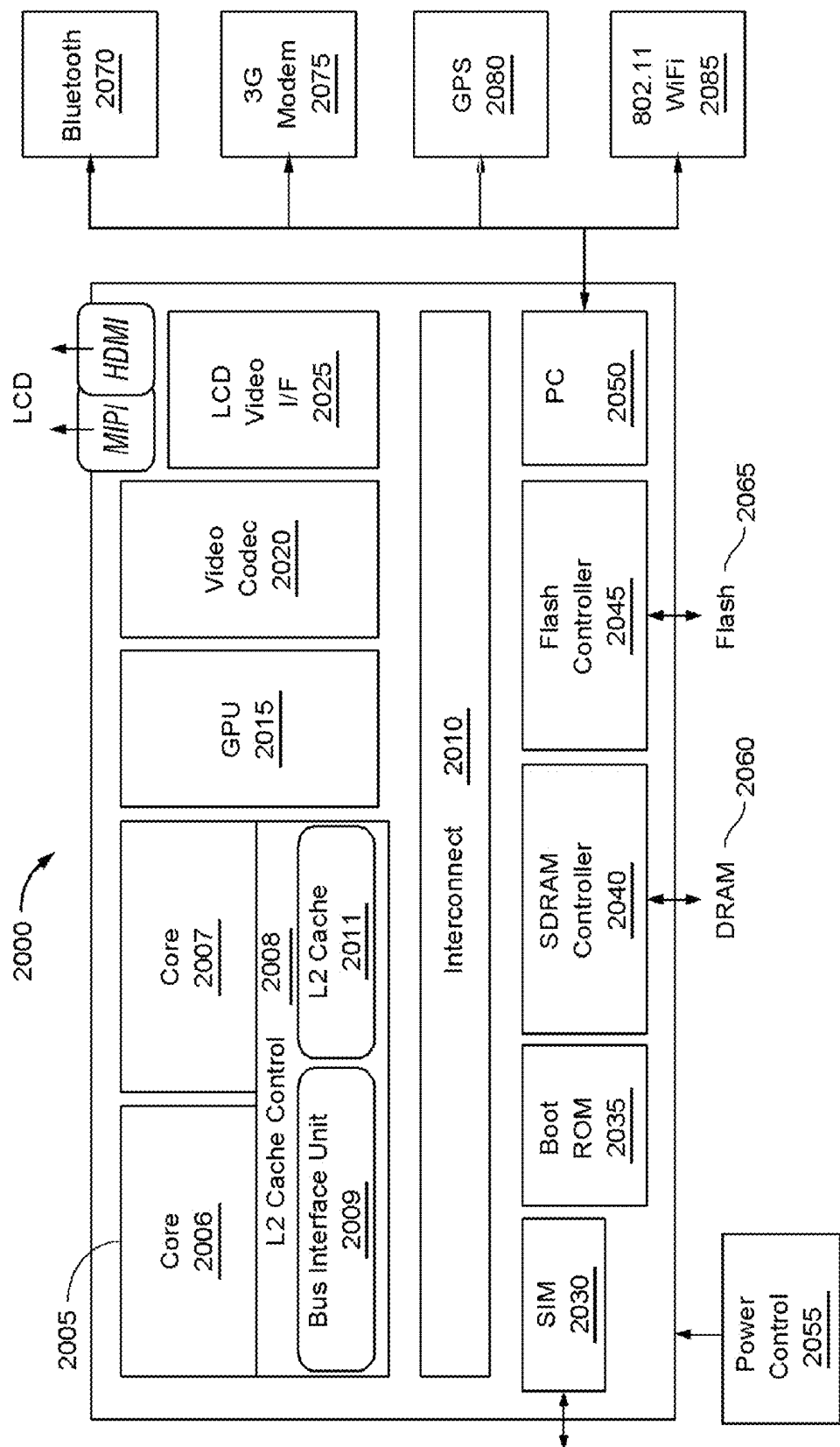


FIG. 8

FUZZY LOGIC CONTROL OF THERMOELECTRIC COOLING IN A PROCESSOR

TECHNICAL FIELD

[0001] Embodiments relate generally to cooling of electronic devices.

BACKGROUND

[0002] Conventionally, a computing device may include a cooling system to remove excess heat produced by electronic components. For example, the cooling system may include a fan to create air flows through the computing device. Such air flows may be used to cool components such as processors, power supplies, memory devices, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIGS. 1A-1B are block diagrams in accordance with one or more embodiments.

[0004] FIGS. 2A-2B are block diagrams in accordance with one or more embodiments.

[0005] FIG. 3 is a sequence in accordance with one or more embodiments.

[0006] FIG. 4 is a block diagram of a processor in accordance with an embodiment of the present invention.

[0007] FIG. 5 is a block diagram of a multi-domain processor in accordance with another embodiment of the present invention.

[0008] FIG. 6 is a block diagram of an embodiment of a processor including multiple cores.

[0009] FIG. 7 is a block diagram of a system in accordance with an embodiment of the present invention.

[0010] FIG. 8 is a block diagram of a system on a chip in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0011] Some computers may include thermoelectric cooling (TEC) devices to remove heat generated by internal components. Such TEC devices may include semiconductor materials which provide a temperature differential when receiving electric power. This temperature differential may increase heat flow from an internal component to a platform cooling device (e.g., air cooling, liquid cooling, etc.). However, in conventional systems, TEC devices and/or platform cooling devices may not be controlled in an efficient manner.

[0012] In accordance with some embodiments, a processor may include fuzzy TEC logic to control a cooling system including a TEC device. The fuzzy TEC logic may include functionality to fuzzify parameters related to the cooling system, including current power levels of the TEC device and the platform cooling device. Further, the fuzzy TEC logic may perform a fuzzy inference to determine new power levels for the TEC device and the platform cooling device. As such, embodiments may provide improved levels of overall cooling efficiency.

[0013] Although the following embodiments may be described with reference to energy conservation and energy efficiency in specific integrated circuits, such as in computing platforms or processors, other embodiments are applicable to other types of integrated circuits and logic devices. Similar techniques and teachings of embodiments described herein may be applied to other types of circuits or semiconductor devices that may also benefit from better energy efficiency

and energy conservation. For example, the disclosed embodiments are not limited to any particular type of computer systems, and may be also used in other devices, such as handheld devices, systems on chip (SoCs), and embedded applications. Some examples of handheld devices include cellular phones, Internet protocol devices, digital cameras, personal digital assistants (PDAs), and handheld PCs. Embedded applications typically include a microcontroller, a digital signal processor (DSP), network computers (NetPC), set-top boxes, network hubs, wide area network (WAN) switches, or any other system that can perform the functions and operations taught below.

[0014] Moreover, the apparatus, methods, and systems described herein are not limited to physical computing devices, but may also relate to software optimizations for energy conservation and efficiency. As will become readily apparent in the description below, the embodiments of methods, apparatus, and systems described herein (whether in reference to hardware, firmware, software, or a combination thereof) are vital to a 'green technology' future, such as for power conservation and energy efficiency in products that encompass a large portion of the US economy.

[0015] Note that embodiments described herein may be independent of and/or complementary to an operating system (OS)-based mechanism, such as the Advanced Configuration and Power Interface (ACPI) standard (e.g., Rev. 3.0b, published Oct. 10, 2006). According to ACPI, a processor can operate at various performance states or levels, namely from P0 to PN. In general, the P1 performance state may correspond to the highest guaranteed performance state that can be requested by an OS. In addition to this P1 state, the OS can further request a higher performance state, namely a P0 state. This P0 state may thus be an opportunistic state in which, when power and/or thermal budget is available, processor hardware can configure the processor or at least portions thereof to operate at a higher than guaranteed frequency. In many implementations a processor can include multiple so-called bin frequencies above a guaranteed maximum frequency, also referred to as a P1 frequency. In addition, according to ACPI, a processor can operate at various power states or levels. With regard to power states, ACPI specifies different power consumption states, generally referred to as C-states, C0, C1 to Cn states. When a core is active, it runs at a C0 state, and when the core is idle it may be placed in a core low power state, also called a core non-zero C-state (e.g., C1-C6 states), with each C-state being at a lower power consumption level (such that C6 is a deeper low power state than C1, and so forth).

[0016] Referring to FIG. 1A, shown is a block diagram of a system 100 in accordance with one or more embodiments. In some embodiments, the system 100 may be all or a portion of an electronic device or component. For example, the system 100 may be included in a cellular telephone, a computer, a server, a network device, a controller, an appliance, a computing blade, a blade enclosure, etc.

[0017] As shown in FIG. 1A, in some embodiments, the system 100 may include a processor 110, memory 108, a fan 134, platform cooling logic (PCL) 112, a heat sink 132, and a thermoelectric cooling (TEC) device 130. In one or more embodiments, the processor 110 may include a temperature sensor 114 and a fuzzy TEC controller 120. Further, the processor 110 may be coupled to the memory 108. The memory 108 may be any type of computer memory (e.g., dynamic random access memory (DRAM), static random-

access memory (SRAM), non-volatile memory, etc.). In some embodiments, the processor 110 may be mounted on or within a package 118.

[0018] In one or more embodiments, the heat sink 132 may be a finned heat exchanger. As shown, the heat sink 132 may be convectively cooled by an air flow 136 provided by the fan 134. Further, in some embodiments, the PCL 112 may control the fan level 133 to vary the amount of convective cooling provided by the air flow 136. For example, the PCL 112 may set the fan level 133 to increase the speed of the fan 134, and therefore increase the convective cooling associated with the air flow 136. The fan level 133 may be, e.g., a power input level, a pulse width modulated (PWM) signal, an indication or command for a particular fan speed, a voltage level, etc.). In some embodiments, each setting of the fan level 133 may correspond to a particular PWM duty cycle and an associated power cost.

[0019] In some embodiments, the TEC device 130 may include a first surface 130a in physical contact with the heat sink 132, and a second surface 130b in physical contact with the processor 110. In some embodiments, the TEC device 130 may receive a TEC power input 122 from the fuzzy TEC controller 120. Further, when receiving the TEC power input 122, the TEC device 130 may provide a temperature differential between the first surface 130a and the second surface 130b. For example, in some embodiments, the TEC device 130 may decrease the temperature on the first surface 130a, and/or may increase the temperature on the second surface 130b. As such, the TEC device 130 may increase a heat flow 138 from the processor 110 to the heat sink 132.

[0020] In some embodiments, the fuzzy TEC controller 120 may control a level of the TEC power input 122 to vary the heat flow 138 provided by the TEC device 130. For example, increasing the TEC level (i.e., the level of the TEC power input 122) may increase the heat flow 138 from the processor 110 to the heat sink 132. In another example, decreasing the TEC level may decrease the heat flow 138. In some embodiments, each setting of the TEC level may correspond to a particular PWM duty cycle and an associated power cost.

[0021] In one or more embodiments, the fuzzy TEC controller 120 may determine the TEC level based at least in part on a temperature value 124 for all or a portion of the processor 110. Further, in some embodiments, this temperature value 124 may be obtained from a temperature sensor 114 included within (or in proximity to) the processor 110.

[0022] In some embodiments, the fuzzy TEC controller 120 may interact and/or coordinate with the PCL 112. For example, the fuzzy TEC controller 120 may obtain the fan level from the PCL 112, and may determine the TEC level based at least in part on the fan level. Further, the fuzzy TEC controller 120 may coordinate with the PCL 112 to control or set the fan level. In one or more embodiments, the fuzzy TEC controller 120 may determine the TEC level and/or the fan level using fuzzy logic functionality. The functionality of the fuzzy TEC controller 120 is described further below with reference to FIGS. 1B and 2A-2B.

[0023] In some embodiments, the fan 134 may be a platform cooling device, meaning a cooling device included in and/or managed by a computing platform. For example, the fan 134 may be included in a computer enclosure, a motherboard, a server cabinet, a blade enclosure, a heat sink, etc. In another example, the fan 134 may be a dedicated fan managed by the PCL 112. As used herein, the term “platform cooling

level” may refer generally to a fan level, and/or to any level or setting for a platform cooling device.

[0024] Note that, while FIG. 1A depicts the system 100 as including the fan 134, embodiments are not limited in this regard. In particular, it is contemplated that some embodiments may use other types of platform cooling devices instead of (or in combination with) the fan 134. For example, in some embodiments, a liquid cooling system may be used to cool the TEC device 130 or the heat sink 132.

[0025] Referring now to FIG. 1B, shown is an example embodiment of a fuzzy TEC controller 120. In this embodiment, the fuzzy TEC controller 120 may include various components, including a switch 144, a pulse width modulation (PWM) unit 142, and fuzzy control logic 154.

[0026] In one or more embodiments, the fuzzy control logic 154 may include functionality to control operation of the TEC device 130 using fuzzy logic. For example, the fuzzy control logic 154 may determine a new TEC level, and may provide an indication 155 of the new TEC level to the PWM unit 142.

[0027] In some embodiments, the fuzzy control logic 154 may determine the new TEC level based on the current state of the processor 110 and/or associated cooling systems. For example, in some embodiments, the fuzzy control logic 154 may obtain the current fan power level 126 from the PCL 112, and/or may obtain the temperature value 124 from the temperature sensor 114. In addition, the fuzzy control logic 154 may obtain any other parameters related to system cooling (e.g., the current TEC power level, a current state of the PCL 112, operating systems commands, etc.). In some embodiments, the fuzzy control logic 154 may also determine a new fan level. The fuzzy control logic 154 may also interact with or control the PCL 112 to set the new fan level.

[0028] In some embodiments, the fuzzy control logic 154 may be triggered periodically (e.g., according to a specified period). Alternatively, the fuzzy control logic 154 may be triggered by internal or external signals, by processor or platform events, etc. The functionality of the fuzzy control logic 154 is described further below with reference to FIGS. 2A-2B.

[0029] In one or more embodiments, the PWM unit 142 may receive the indication 155 of the new TEC level, and may generate a duty cycle signal 143 (e.g., a given number of pulses per time unit) based on the new TEC level. As shown, the duty cycle signal 143 may be provided to the switch 144. In some embodiments, the switch 144 may switch a power input 121 on and off based on the duty cycle signal 143, and may output a pulsed power supply 122. In one or more embodiments, the pulsed power supply 122 may power the TEC device 130 at the new TEC level.

[0030] Referring now to FIG. 2A, shown is an example embodiment of the fuzzy control logic 154. In this embodiment, the fuzzy TEC controller 120 may include various components, including fuzzification logic 210, fuzzy rules 220, inference logic 230, de-fuzzification logic 240, and a parameter tuner 250.

[0031] In one or more embodiments, the fuzzification logic 210 may receive one or more input values. For example, such input values may include a current fan level 202, a current TEC level 204, and/or a current temperature value 206. In some embodiments, such inputs may be “crisp” or quantified values (e.g., a fan level expressed as a number of pulses per time unit, a TEC level expressed as a number of pulses per time unit, a temperature value expressed as a number of degrees Celsius, etc.).

[0032] In some embodiments, the fuzzification logic 210 may include functionality to “fuzzify” the input values, meaning to convert from a crisp value to a fuzzy value. Referring now to FIG. 2B, shown is an example graph 250 illustrating the functionality of the fuzzification logic 210. In particular, the graph 250 illustrates an example of membership functions that implement three non-numeric or linguistic values of a fan level. In this example, the first curve 260 may correspond to the fuzzy set “SLOW,” the second curve 265 may correspond to the fuzzy set “MEDIUM,” and the third curve 270 may correspond to the fuzzy set “FAST.” These curves may be used to determine the degree of membership of a given input in each fuzzy set.

[0033] Referring again to FIG. 2A, the fuzzification logic 210 may include functionality to map a current fan level 202 to defined fuzzy sets (e.g., curves 260, 265, 270 shown in FIG. 2B), and thereby obtain an abstracted fan level (referred to as a first “fuzzy fan level”). Further, the fuzzification logic 210 may include functionality to also map a current TEC level 204 to the defined fuzzy sets, and thereby obtain a second fuzzy fan level. Thus, by abstracting a TEC level as fuzzy fan level, the fuzzification logic 210 may enable any number of fan levels and TEC levels to be combined into a unified fuzzy control model.

[0034] In one or more embodiments, the fuzzification logic 210 may include a thermal model of the processor 110, the fan 134, and/or the TEC device 130. The processor 110 consumes power to perform computational work, and produces heat as a byproduct. Thus, whenever the processor 110 executes a workload, its temperature rises, and the fan 134 and the TEC device 130 cool the processor 110 to counterbalance this rise in temperature. In some embodiments, at any given instant of time, the temperature of the processor 110 may be modeled as a cumulative average of past and current workload, and a regression of past and current cooling delivered by the fans and TEC devices together.

[0035] In some embodiments, the thermal model included in the fuzzification logic 210 may predict the temperature based on the current power and temperature, fuzzy rules applied for the current fan PWM and TEC input duty cycles, and/or the predicted temperature at next sampling instant based on the current power. For example, the thermal model included in the fuzzification logic 210 may be based on a Resistance Capacitor (RC) network model.

[0036] In one or more embodiments, the fuzzification logic 210 may provide one or more fuzzy fan values to the fuzzy rules 220. In some embodiments, each fuzzy rule 220 may have the general form IF antecedent THEN consequent. For instance, assume the variable z represents a fuzzy fan value, and the variable y represents a temperature value. In some embodiments, each rule may produce a temperature y that is influenced by the membership function M of each fuzzy fan value z . Thus, the fuzzy rules 220 may be illustrated by the following example rules.

[0037] Rule 1: If z_1 =“SLOW” and z_2 =“SLOW” then y_1 =40 degrees

[0038] Rule 2: If z_1 =“SLOW” and z_2 =“MEDIUM” then y_2 =45 degrees

[0039] Rule 3: If z_1 =“MEDIUM” and z_2 =“SLOW” then y_3 =47 degrees

[0040] In one or more embodiments, the results of the fuzzy rules 220 may be provided to the inference logic 230. The inference logic 230 may include functionality to derive a fuzzy inference based on a weighted combination of the out-

puts from each fuzzy rule 220. For example, assume that the fuzzy rules 220 include n rules, each associated with a normalized weight factor w . Each normalized weight factor w , may correspond to the relative contribution of the rule i to a fuzzy inference. Thus, the fuzzy inference $f(Z)$ for a net estimated temperature may have the following form:

$$f(Z)=w_1y_1+w_2y_2+w_3y_3+\dots+w_ny_n$$

[0041] In one or more embodiments, assuming n fuzzy rules, the normalized weight factor w , may be computed using the following formula:

$$w_j=M_j/(M_1+M_2+\dots+M_n)$$

[0042] Here, M_j is the degree of membership or membership function for the fuzzy input j . For example, assume that, for a fuzzy fan value $z=0.3$, the “SLOW” membership function M_1 is 0.63, the “MEDIUM” membership function M_2 is 0.31, and the “FAST” membership function M_3 is 0.0. Thus, in this example, the corresponding weight factors may be $w_1=0.63$, $w_2=0.31$, and $w_3=0.0$.

[0043] In one or more embodiments, the temperature y may be obtained using a parameter adaptation algorithm (PAA) method. The PAA method may assume that the die temperature at a given sampling instant t is proportional to the current power consumption of the die, plus the power already consumed till the instant t . Further, the PAA method may assume that power consumption in the processor die is dissipated as heat. In addition, the PAA method may assume that the die temperature at the instant t is regressively reduced through the cooling action of the fan and the TEC device. In some embodiments, the instantaneous die temperature may be dependent on the amount of computing work performed by the processor, and the cumulative cooling received by the processor until instant t . For a given rule, the temperature y at an instant $(t+1)$ may be expressed as follows:

$$y(t+1)=aP(t)+bT(t)$$

[0044] Here, $P(t)$ is the instantaneous power consumed by the die at time instant t . Further, $T(t)$ is the accumulated balance temperature remaining in the die at time instant t . The parameters a and b can be obtained using the PAA method, for example through a dummy workload applied in a controlled laboratory environment, or by measuring the active workload running on the die in the field. Once the parameters a and b are determined, it is possible to predict future die temperatures by observing the current power consumed, the current die temperature, and recording the current output of the fuzzy rules based on the parameters a and b .

[0045] In some embodiments, the de-fuzzification logic 240 may include functionality to de-fuzzify the output of the inference logic 230. For example, the de-fuzzification logic 240 may convert a fuzzy value provided by the inference logic 230 to a crisp value (e.g., a net estimated temperature measured in degrees Celsius).

[0046] In one or more embodiments, the parameter tuner 250 may include functionality to evaluate a cost factor associated with each fuzzy rule 220. In some embodiments, the cost factor for each fuzzy rule may be based on the power consumption associated with a cooling system. For example, referring to FIG. 1A, the cost factor for a given fuzzy rule may be based on the amount of cumulative power consumed by the fan 134 and the TEC device 130 when operated at levels associated with that fuzzy rule. Further, the cost factor may also include the amount of power associated with heat leak-

age in the TEC device. For example, the cost factor C for fuzzy rule R may be represented by the following formula:

$$C(z_1, z_2 | R) = P_F(z_1) + P_T(z_2) + P_L(y_1)$$

[0047] In the above formula for cost factor C, the term $P_F(z_1)$ represents the power consumed by a fan, $P_T(z_2)$ represents the power consumed by a TEC device, and $P_L(y_1)$ represents the power associated with heat leakage in the TEC device. In some embodiments, the fan power P_F may be determined using the Fan Power law that relates the fan rotation speed r to its power consumption. For example, the fan power P_F may be determined using the following formula:

$$P_F = (r)^3$$

[0048] In some embodiments, the TEC power P_T may be determined using the coefficient of performance (CoP) of the TEC device. For example, the TEC power P_T may be determined using the following formula:

$$P_T = Q_c / \text{CoP}$$

[0049] In the above formula for TEC power P_T , the term Q_c is the rate of heat generated (e.g., by the processor 110). In some embodiments, the rate of heat Q_c may depend on the computing workload of the processor 110. Further, the rate of heat Q_c may be expressed by the following formula:

$$Q_c = I^2 S^2 T_c - K(T_h - T_c) - (R^2 P^2) / 2$$

[0050] In the above formula for the rate of heat Q_c , I is the current input to the TEC device, S is the Seebeck constant, K is the conductance of the TEC device, R is the resistance of the TEC device, T_h is the temperature at the hot side of the TEC device, and T_c is the temperature at the cold side of the TEC device. The first term in this equation represents the Peltier cooling action of the TEC device 130, the second term represents the heat leakage from the hot side to the cold side of the TEC device, and the third term represents the Joule effect.

[0051] In some embodiments, the heat leakage power P_L from the hot side to the cold side of the TEC device may be determined using the second term of the formula for the rate of heat Q_c . For example, the heat leakage power P_L may be determined using the following formula:

$$P_L = K(T_h - T_c)$$

[0052] In one or more embodiments, the parameter tuner 250 may include functionality to determine a prediction error. In some embodiments, the prediction error may be based on a difference between the predicted temperature and the actual measured temperature.

[0053] In one or more embodiments, the parameter tuner 250 may include functionality to determine a new TEC power level 208 and/or a new fan level 209 based on outputs of the de-fuzzification logic 240. In some embodiments, this functionality may use a predictive control loop to minimize an objective function based on the cost factor and/or the prediction error. For example, the parameter tuner 250 may evaluate fuzzy inferences associated with various TEC power levels 208 and fan levels 209. The parameter tuner 250 may then select a particular combination of TEC power level 208 and fan level 209 based on minimizing the associated cost factor and/or prediction error. In some embodiments, the parameter tuner 250 may use any optimization technique, including linear programming, heuristics, multi-objective optimization, etc. In one or more embodiments, the new TEC power level 208 may be used to provide power to a TEC device (e.g., TEC device 130 shown in FIG. 1A). Further, the new fan level

209 may be used to provide power to a platform cooling device (e.g., fan 134 shown in FIG. 1A).

[0054] Referring now to FIG. 3, shown is a sequence 300 for controlling a cooling system, in accordance with one or more embodiments. In one or more embodiments, the sequence 300 may be part of the fuzzy TEC controller 120 shown in FIGS. 1A-1B. The sequence 300 may be implemented in hardware, software, and/or firmware. In firmware and software embodiments it may be implemented by computer executed instructions stored in a non-transitory computer readable medium, such as an optical, semiconductor, or magnetic storage device.

[0055] At step 310, a current fan level may be determined. For example, referring to FIG. 1A, the fuzzy TEC controller 120 may determine the level of the fan level 133 provided to the fan 134. In some embodiments, the fuzzy TEC controller 120 may interact with the PCL 112 to determine the current fan level.

[0056] At step 320, a current TEC level may be determined. For example, referring to FIG. 1A, the fuzzy TEC controller 120 may determine the current level of the TEC device. In some embodiments, the fuzzy TEC controller 120 may store the current TEC level in a register, internal memory, etc.

[0057] At step 330, a current temperature may be determined. For example, referring to FIG. 1A, the fuzzy TEC controller 120 may read the temperature value 124 from the temperature sensor 114 included in the processor 110.

[0058] At step 340, input values may be fuzzified. For example, referring to FIG. 2A, the fuzzification logic 210 may fuzzify one or more of the current fan level 202, the current TEC level 204, and/or the current temperature value 206, thereby converting these inputs from crisp values to a fuzzy values. In some embodiments, the current TEC level 204 may be abstracted as a fuzzy fan level.

[0059] At step 350, fuzzy rules may be evaluated using the fuzzified inputs. For example, referring to FIG. 2A, the fuzzy rules 220 may be evaluated using the fuzzified values provided by the fuzzification logic 210.

[0060] At step 360, an estimated temperature may be estimated using fuzzy inference. For example, referring to FIG. 2A, the inference logic 230 may include functionality to derive a fuzzy inference based on a weighted combination of the outputs from each fuzzy rule 220. In some embodiments, each fuzzy rule 220 may be associated with a particular weight factor w .

[0061] At step 370, the output of the fuzzy inference may be de-fuzzified. For example, referring to FIG. 2A, the de-fuzzification logic 240 may de-fuzzify the estimated temperature provided by the inference logic 230.

[0062] At step 380, new settings may be determined based on a cost factor and/or a prediction error. For example, referring to FIG. 2A, the parameter tuner 250 may select a new TEC level and/or new fan level based on minimizing a cost factor and/or a prediction error. In some embodiments, the cost factor associated with each fuzzy rule 220 may be based on the amount of cumulative power consumed by the fan 134 and the TEC device 130 when operated at levels associated with that fuzzy rule 220. Further, in some embodiments, the prediction error may be based on a difference between the predicted temperature and the actual measured temperature.

[0063] At step 390, the fan and/or the TEC device may be operated according to the new settings. For example, referring to FIG. 1B, the fuzzy TEC controller 120 may interact or set the PCL 112 to operate the fan 134 at the new fan level. In

addition, the fuzzy TEC controller **120** may provide the pulsed power supply **122** to the TEC device **130** at the new TEC level. After step **390**, the sequence **300** ends.

[0064] Note that the examples shown in FIGS. **1A-1B**, **2A-2B**, and **3** are provided for the sake of illustration, and are not intended to limit any embodiments. For instance, while embodiments are shown as including platform cooling systems based on fans (e.g., fan **134**), other platform cooling systems may be used (e.g., a liquid cooling system). Further, it is contemplated that cooling systems may include any number or combination of fans and/or TEC devices. Furthermore, while FIG. **2B** depicts particular examples of fuzzy sets, embodiments may include any type and/or number of fuzzy sets (e.g., low/high, very low, very high, etc.). In addition, while embodiments may be shown in simplified form for the sake of clarity, embodiments may include any number and/or arrangement of processors, cores, and/or additional components (e.g., buses, storage media, connectors, power components, buffers, interfaces, etc.). It is contemplated that specifics in the examples shown in FIGS. **1A-1B**, **2A-2B**, and **3** may be used anywhere in one or more embodiments.

[0065] Referring now to FIG. **4**, shown is a block diagram of a processor in accordance with an embodiment of the present invention. As shown in FIG. **4**, the processor **400** may be a multicore processor including first die **405** having a plurality of cores **410a-410n** of a core domain. The various cores **410a-410n** may be coupled via an interconnect **415** to a system agent or uncore domain that includes various components. As seen, the uncore domain may include a shared cache **430**. In addition, the uncore may include an integrated memory controller **440**, a power control unit (PCU) **470**, and various interfaces **450**.

[0066] Although not shown for ease of illustration in FIG. **4**, in some embodiments, the processor **400** may include some or all of the functionality of the fuzzy TEC controller **120** and/or the TEC device **130** described above with reference to FIGS. **1A-1B**.

[0067] With further reference to FIG. **4**, the processor **400** may communicate with a system memory **460**, e.g., via a memory bus. In addition, by interfaces **450**, connection can be made to another processor, or various off-package components such as peripheral devices, mass storage and so forth. While shown with this particular implementation in the embodiment of FIG. **4**, the scope of the present invention is not limited in this regard.

[0068] Referring now to FIG. **5**, shown is a block diagram of a multi-domain processor in accordance with another embodiment of the present invention. As shown in the embodiment of FIG. **5**, processor **500** includes multiple domains. Specifically, a core domain **510** can include a plurality of cores **510a-510n**, a graphics domain **520** can include one or more graphics engines, and a system agent domain **550** may further be present. Note that while only shown with three domains, understand the scope of the present invention is not limited in this regard and additional domains can be present in other embodiments. For example, multiple core domains may be present each including at least one core.

[0069] In general, each core **510** may further include low level caches in addition to various execution units and additional processing elements. In turn, the various cores may be coupled to each other and to a shared cache memory formed of a plurality of units of a last level cache (LLC) **540a-540n**.

In various embodiments, LLC **540** may be shared amongst the cores and the graphics engine, as well as various media processing circuitry.

[0070] As seen, a ring interconnect **530** thus couples the cores together, and provides interconnection between the cores, graphics domain **520** and system agent circuitry **550**. In some embodiments, the ring interconnect **530** may be a multiplexor or crossbar device. In the embodiment of FIG. **5**, system agent domain **550** may include display controller **552** which may provide control of and an interface to an associated display. As further seen, system agent domain **550** may also include a power control unit **555** to allocate power to the core and non-core domains.

[0071] As further seen in FIG. **5**, processor **500** can further include an integrated memory controller (IMC) **570** that can provide for an interface to a system memory, such as a dynamic random access memory (DRAM). Multiple interfaces **580a-580n** may be present to enable interconnection between the processor and other circuitry. For example, in one embodiment at least one direct media interface (DMI) interface may be provided as well as one or more Peripheral Component Interconnect Express (PCI Express™ (PCIe™)) interfaces. Still further, to provide for communications between other agents such as additional processors or other circuitry, one or more interfaces in accordance with an Intel® Quick Path Interconnect (QPI) protocol may also be provided. As further seen, a peripheral controller hub (PCH) **590** may also be present within the processor **500**, and can be implemented on a separate die, in some embodiments. Alternatively, in some embodiments, the PCH **590** may be external to the processor **500**. Although shown at this high level in the embodiment of FIG. **5**, understand the scope of the present invention is not limited in this regard.

[0072] Although not shown for ease of illustration in FIG. **5**, in some embodiments, the processor **500** may include some or all of the functionality of the fuzzy TEC controller **120** and/or the TEC device **130** described above with reference to FIGS. **1A-1B**.

[0073] Referring to FIG. **6**, an embodiment of a processor including multiple cores is illustrated. Processor **1100** includes any processor or processing device, such as a micro-processor, an embedded processor, a digital signal processor (DSP), a network processor, a handheld processor, an application processor, a co-processor, a system on a chip (SOC), or other device to execute code. Processor **1100**, in one embodiment, includes at least two cores—cores **1101** and **1102**, which may include asymmetric cores or symmetric cores (the illustrated embodiment). However, processor **1100** may include any number of processing elements that may be symmetric or asymmetric.

[0074] In one embodiment, a processing element refers to hardware or logic to support a software thread. Examples of hardware processing elements include: a thread unit, a thread slot, a thread, a process unit, a context, a context unit, a logical processor, a hardware thread, a core, and/or any other element, which is capable of holding a state for a processor, such as an execution state or architectural state. In other words, a processing element, in one embodiment, refers to any hardware capable of being independently associated with code, such as a software thread, operating system, application, or other code. A physical processor typically refers to an integrated circuit, which potentially includes any number of other processing elements, such as cores or hardware threads.

[0075] A core often refers to logic located on an integrated circuit capable of maintaining an independent architectural state, wherein each independently maintained architectural state is associated with at least some dedicated execution resources. In contrast to cores, a hardware thread typically refers to any logic located on an integrated circuit capable of maintaining an independent architectural state, wherein the independently maintained architectural states share access to execution resources. As can be seen, when certain resources are shared and others are dedicated to an architectural state, the line between the nomenclature of a hardware thread and core overlaps. Yet often, a core and a hardware thread are viewed by an operating system as individual logical processors, where the operating system is able to individually schedule operations on each logical processor.

[0076] Physical processor **1100**, as illustrated in FIG. 6, includes two cores, cores **1101** and **1102**. Here, cores **1101** and **1102** are considered symmetric cores, i.e. cores with the same configurations, functional units, and/or logic. In another embodiment, core **1101** includes an out-of-order processor core, while core **1102** includes an in-order processor core. However, cores **1101** and **1102** may be individually selected from any type of core, such as a native core, a software managed core, a core adapted to execute a native instruction set architecture (ISA), a core adapted to execute a translated ISA, a co-designed core, or other known core. Yet to further the discussion, the functional units illustrated in core **1101** are described in further detail below, as the units in core **1102** operate in a similar manner.

[0077] As shown, core **1101** includes two hardware threads **1101a** and **1101b**, which may also be referred to as hardware thread slots **1101a** and **1101b**. Therefore, software entities, such as an operating system, in one embodiment potentially view processor **1100** as four separate processors, i.e., four logical processors or processing elements capable of executing four software threads concurrently. As alluded to above, a first thread is associated with architecture state registers **1101a**, a second thread is associated with architecture state registers **1101b**, a third thread may be associated with architecture state registers **1102a**, and a fourth thread may be associated with architecture state registers **1102b**. Here, each of the architecture state registers (**1101a**, **1101b**, **1102a**, and **1102b**) may be referred to as processing elements, thread slots, or thread units, as described above.

[0078] As illustrated, architecture state registers **1101a** are replicated in architecture state registers **1101b**, so individual architecture states/contexts are capable of being stored for logical processor **1101a** and logical processor **1101b**. In core **1101**, other smaller resources, such as instruction pointers and renaming logic in allocator and renamer block **1130** may also be replicated for threads **1101a** and **1101b**. Some resources, such as re-order buffers in reorder/retirement unit **1135**, ILTB **1120**, load/store buffers, and queues may be shared through partitioning. Other resources, such as general purpose internal registers, page-table base register(s), low-level data-cache and data-TLB **1115**, execution unit(s) **1140**, and portions of out-of-order unit **1135** are potentially fully shared.

[0079] Processor **1100** often includes other resources, which may be fully shared, shared through partitioning, or dedicated by/to processing elements. In FIG. 6, an embodiment of a purely exemplary processor with illustrative logical units/resources of a processor is illustrated. Note that a processor may include, or omit, any of these functional units, as

well as include any other known functional units, logic, or firmware not depicted. As illustrated, core **1101** includes a simplified, representative out-of-order (OOO) processor core. But an in-order processor may be utilized in different embodiments. The OOO core includes a branch target buffer **1120** to predict branches to be executed/taken and an instruction-translation buffer (I-TLB) **1120** to store address translation entries for instructions.

[0080] Core **1101** further includes decode module **1125** coupled to fetch unit **1120** to decode fetched elements. Fetch logic, in one embodiment, includes individual sequencers associated with thread slots **1101a**, **1101b**, respectively. Usually core **1101** is associated with a first ISA, which defines/specifies instructions executable on processor **1100**. Often machine code instructions that are part of the first ISA include a portion of the instruction (referred to as an opcode), which references/specifies an instruction or operation to be performed. Decode logic **1125** includes circuitry that recognizes these instructions from their opcodes and passes the decoded instructions on in the pipeline for processing as defined by the first ISA. As a result of the recognition by decoders **1125**, the architecture or core **1101** takes specific, predefined actions to perform tasks associated with the appropriate instruction. It is important to note that any of the tasks, blocks, operations, and methods described herein may be performed in response to a single or multiple instructions; some of which may be new or old instructions.

[0081] In one example, allocator and renamer block **1130** includes an allocator to reserve resources, such as register files to store instruction processing results. However, threads **1101a** and **1101b** are potentially capable of out-of-order execution, where allocator and renamer block **1130** also reserves other resources, such as reorder buffers to track instruction results. Unit **1130** may also include a register renamer to rename program/instruction reference registers to other registers internal to processor **1100**. Reorder/retirement unit **1135** includes components, such as the reorder buffers mentioned above, load buffers, and store buffers, to support out-of-order execution and later in-order retirement of instructions executed out-of-order.

[0082] Scheduler and execution unit(s) block **1140**, in one embodiment, includes a scheduler unit to schedule instructions/operation on execution units. For example, a floating point instruction is scheduled on a port of an execution unit that has an available floating point execution unit. Register files associated with the execution units are also included to store information instruction processing results. Exemplary execution units include a floating point execution unit, an integer execution unit, a jump execution unit, a load execution unit, a store execution unit, and other known execution units.

[0083] Lower level data cache and data translation buffer (D-TLB) **1150** are coupled to execution unit(s) **1140**. The data cache is to store recently used/operated on elements, such as data operands, which are potentially held in memory coherency states. The D-TLB is to store recent virtual/linear to physical address translations. As a specific example, a processor may include a page table structure to break physical memory into a plurality of virtual pages.

[0084] Here, cores **1101** and **1102** share access to higher-level or further-out cache **1110**, which is to cache recently fetched elements. Note that higher-level or further-out refers to cache levels increasing or getting further away from the execution unit(s). In one embodiment, higher-level cache **1110** is a last-level data cache—last cache in the memory

hierarchy on processor **1100**—such as a second or third level data cache. However, higher level cache **1110** is not so limited, as it may be associated with or includes an instruction cache. A trace cache—a type of instruction cache—instead may be coupled after decoder **1125** to store recently decoded traces. In the depicted configuration, processor **1100** also includes bus interface module **1105** and a power controller **1160**, which may perform power management in accordance with an embodiment of the present invention.

[0085] Historically, controller **1170** has been included in a computing system external to processor **1100**. In this scenario, bus interface **1105** is to communicate with devices external to processor **1100**, such as system memory **1175**, a chipset (often including a memory controller hub to connect to memory **1175** and an I/O controller hub to connect peripheral devices), a memory controller hub, a northbridge, or other integrated circuit. And in this scenario, bus **1105** may include any known interconnect, such as multi-drop bus, a point-to-point interconnect, a serial interconnect, a parallel bus, a coherent (e.g. cache coherent) bus, a layered protocol architecture, a differential bus, and a GTL bus.

[0086] Memory **1175** may be dedicated to processor **1100** or shared with other devices in a system. Common examples of types of memory **1175** include DRAM, SRAM, non-volatile memory (NV memory), and other known storage devices. Note that device **1180** may include a graphic accelerator, processor or card coupled to a memory controller hub, data storage coupled to an I/O controller hub, a wireless transceiver, a flash device, an audio controller, a network controller, or other known device.

[0087] Note however, that in the depicted embodiment, the controller **1170** is illustrated as part of processor **1100**. Recently, as more logic and devices are being integrated on a single die, such as SOC, each of these devices may be incorporated on processor **1100**. For example in one embodiment, memory controller hub **1170** is on the same package and/or die with processor **1100**. Here, a portion of the core (an on-core portion) includes one or more controller(s) **1170** for interfacing with other devices such as memory **1175** or a graphics device **1180**. The configuration including an interconnect and controllers for interfacing with such devices is often referred to as an on-core (or un-core configuration). As an example, bus interface **1105** includes a ring interconnect with a memory controller for interfacing with memory **1175** and a graphics controller for interfacing with graphics processor **1180**. Yet, in the SOC environment, even more devices, such as the network interface, co-processors, memory **1175**, graphics processor **1180**, and any other known computer devices/interface may be integrated on a single die or integrated circuit to provide small form factor with high functionality and low power consumption.

[0088] Although not shown for ease of illustration in FIG. 6, in some embodiments, the processor **1100** may include some or all of the functionality of the fuzzy TEC controller **120** and/or the TEC device **130** described above with reference to FIGS. 1A-1B.

[0089] Embodiments may be implemented in many different system types. Referring now to FIG. 7, shown is a block diagram of a system in accordance with an embodiment of the present invention. As shown in FIG. 7, multiprocessor system **600** is a point-to-point interconnect system, and includes a first processor **670** and a second processor **680** coupled via a point-to-point interconnect **650**. As shown in FIG. 7, each of processors **670** and **680** may be multicore processors, includ-

ing first and second processor cores (i.e., processor cores **674a** and **674b** and processor cores **684a** and **684b**), although potentially many more cores may be present in the processors.

[0090] Still referring to FIG. 7, first processor **670** further includes a memory controller hub (MCH) **672** and point-to-point (P-P) interfaces **676** and **678**. Similarly, second processor **680** includes a MCH **682** and P-P interfaces **686** and **688**. As shown in FIG. 7, MCH's **672** and **682** couple the processors to respective memories, namely a memory **632** and a memory **634**, which may be portions of system memory (e.g., DRAM) locally attached to the respective processors. First processor **670** and second processor **680** may be coupled to a chipset **690** via P-P interconnects **652** and **654**, respectively. As shown in FIG. 7, chipset **690** includes P-P interfaces **694** and **698**.

[0091] Furthermore, chipset **690** includes an interface **692** to couple chipset **690** with a high performance graphics engine **638**, by a P-P interconnect **639**. In turn, chipset **690** may be coupled to a first bus **616** via an interface **696**. As shown in FIG. 7, various input/output (I/O) devices **614** may be coupled to first bus **616**, along with a bus bridge **618** which couples first bus **616** to a second bus **620**. Various devices may be coupled to second bus **620** including, for example, a keyboard/mouse **622**, communication devices **626** and a data storage unit **628** such as a disk drive or other mass storage device which may include code **630**, in one embodiment. Further, an audio I/O **624** may be coupled to second bus **620**. Embodiments can be incorporated into other types of systems including mobile devices such as a smart cellular telephone, tablet computer, netbook, Ultrabook™, or so forth.

[0092] Although not shown for ease of illustration in FIG. 7, in some embodiments, any portion of the multiprocessor system **600** may include some or all of the functionality of the fuzzy TEC controller **120** and/or the TEC device **130** described above with reference to FIGS. 1A-1B.

[0093] It should be understood that a processor core may support multithreading (executing two or more parallel sets of operations or threads), and may do so in a variety of ways including time sliced multithreading, simultaneous multithreading (where a single physical core provides a logical core for each of the threads that physical core is simultaneously multithreading), or a combination thereof (e.g., time sliced fetching and decoding and simultaneous multithreading thereafter such as in the Intel® Hyperthreading technology).

[0094] Any processor described herein may be a general-purpose processor, such as a Core™ i3, i5, i7, 2 Duo and Quad, Xeon™, Itanium™, XScale™ or StrongARM™ processor, which are available from Intel Corporation, of Santa Clara, Calif. Alternatively, the processor may be from another company, such as ARM Holdings, Ltd, MIPS, etc. The processor may be a special-purpose processor, such as, for example, a network or communication processor, compression engine, graphics processor, co-processor, embedded processor, or the like. The processor may be implemented on one or more chips. The processor may be a part of and/or may be implemented on one or more substrates using any of a number of process technologies, such as, for example, BiCMOS, CMOS, or NMOS.

[0095] It is contemplated that the processors described herein are not limited to any system or device. Other system designs and configurations known in the arts for laptops, desktops, handheld PCs, personal digital assistants, engineer-

ing workstations, servers, network devices, network hubs, switches, embedded processors, digital signal processors (DSPs), graphics devices, video game devices, set-top boxes, micro controllers, cell phones, portable media players, hand held devices, and various other electronic devices, are also suitable. In general, a huge variety of systems or electronic devices capable of incorporating a processor and/or other execution logic as disclosed herein are generally suitable.

[0096] Turning next to FIG. 8, an example of a system on-chip (SOC) design in accordance with some embodiments is depicted. As a specific illustrative example, SOC **2000** is included in user equipment (UE). In one embodiment, UE refers to any device to be used by an end-user to communicate, such as a hand-held phone, smartphone, tablet, ultra-thin notebook, notebook with broadband adapter, or any other similar communication device. Often a UE connects to a base station or node, which potentially corresponds in nature to a mobile station (MS) in a GSM network. In some embodiments, SOC **2000** may include some or all of the functionality of the fuzzy TEC controller **120** and/or the TEC device **130** described above with reference to FIGS. 1A-1B.

[0097] Here, SOC **2000** includes 2 cores—**2006** and **2007**. The cores **2006** and **2007** may conform to an Instruction Set Architecture, such as an Intel® Architecture Core™-based processor, an Advanced Micro Devices, Inc. (AMD) processor, a MIPS-based processor, an ARM-based processor design, or a customer thereof, as well as their licensees or adopters. Cores **2006** and **2007** are coupled to cache control **2008** that is associated with bus interface unit **2009** and L2 cache **2011** to communicate with other parts of system **2000**. Interconnect **2010** includes an on-chip interconnect, such as an IOSF, AMBA, or any other interconnect, which potentially implements one or more aspects of the described invention.

[0098] Interface **2010** provides communication channels to the other components, such as a Subscriber Identity Module (SIM) **2030** to interface with a SIM card, a boot ROM **2035** to hold boot code for execution by cores **2006** and **2007** to initialize and boot SOC **2000**, a SDRAM controller **2040** to interface with external memory (e.g. DRAM **2060**), a flash controller **2045** to interface with non-volatile memory (e.g. Flash **2065**), a peripheral control **Q1650** (e.g. Serial Peripheral Interface) to interface with peripherals, video codecs **2020** and Video interface **2025** to display and receive input (e.g. touch enabled input), GPU **2015** to perform graphics related computations, etc.

[0099] In addition, the system illustrates peripherals for communication, such as a Bluetooth module **2070**, 3G modem **2075**, GPS **2085**, and WiFi **2085**. Note that a UE includes a radio for communication. As a result, these peripheral communication modules are not all required. However, in a UE some form a radio for external communication is to be included.

[0100] Embodiments may be implemented in code and may be stored on a non-transitory storage medium having stored thereon instructions which can be used to program a system to perform the instructions. The storage medium may include, but is not limited to, any type of disk including floppy disks, optical disks, solid state drives (SSDs), compact disk read-only memories (CD-ROMs), compact disk rewritables (CD-RWs), and magneto-optical disks, semiconductor devices such as read-only memories (ROMs), random access memories (RAMs) such as dynamic random access memories (DRAMs), static random access memories (SRAMs), erasable programmable read-only memories (EPROMs), flash

memories, electrically erasable programmable read-only memories (EEPROMs), magnetic or optical cards, or any other type of media suitable for storing electronic instructions.

[0101] The following clauses and/or examples pertain to further embodiments. In one example embodiment may be a processor including a fuzzy thermoelectric cooling (TEC) controller. The fuzzy TEC controller may be to: obtain a current TEC level associated with the processor; obtain a current fan power level associated with the processor; fuzzify the current TEC level to obtain a first fuzzy fan level; fuzzify the current fan power level to obtain a second fuzzy fan level; determine a new TEC power level based at least in part on the first fuzzy fan level, the second fuzzy fan level, and a plurality of fuzzy rules; and provide the new TEC power level to a TEC device associated with the processor, wherein the TEC device is to transfer heat from the processor to a heat sink.

[0102] In an example, the fuzzy TEC controller is further to calculate a new fan power level based at least in part on the first fuzzy fan level, the second fuzzy fan level, and the plurality of fuzzy rules.

[0103] In an example, the fuzzy TEC controller is further to provide the new fan power level to least one cooling fan providing an air flow to the heat sink.

[0104] In an example, the fuzzy TEC controller is further to obtain a current temperature associated with the processor. In an example, the fuzzy TEC controller is further to determine the new TEC power level using the current temperature.

[0105] In an example, the fuzzy TEC controller is further to: evaluate, using at least the first fuzzy fan level and the second fuzzy fan level, the plurality of fuzzy rules to obtain a plurality of fuzzy outputs; and perform a fuzzy inference using the plurality of fuzzy outputs. In an example, the fuzzy TEC controller is further to de-fuzzify each of the plurality of fuzzy outputs to obtain quantities.

[0106] In an example, the fuzzy TEC controller is to determine the new TEC power level based at least in part on reducing a cost factor associated with each of the plurality of fuzzy rules. In an example, the cost factor associated with each of the plurality of fuzzy rules may be based at least in part on an amount of power consumed by a fan and an amount of power consumed by the TEC device. In an example, the cost factor associated with each of the plurality of fuzzy rules is further based at least in part on an amount of power associated with heat leakage in the TEC device.

[0107] In an example, the fuzzy TEC controller is to determine the new TEC power level based at least in part on reducing a prediction error associated with each of the plurality of fuzzy rules.

[0108] In another example embodiment may be a system including a processor, a fuzzy thermoelectric cooling (TEC) controller, a heat sink, at least one TEC device, and a dynamic random access memory (DRAM) coupled to the processor. The processor may include at least one core to execute instructions. The fuzzy TEC controller may be to: fuzzify a current TEC level to obtain a first fuzzy fan level; fuzzify a current fan power level to obtain a second fuzzy fan level; evaluate, using at least the first fuzzy fan level and the second fuzzy fan level, a plurality of fuzzy rules to obtain a plurality of fuzzy outputs; determine a new TEC power level based at least in part on the plurality of fuzzy outputs. The at least one TEC device may be to transfer heat from the processor to the heat sink based on the new TEC power level.

[0109] In an example, the system may further include at least one fan providing an air flow to the heat sink.

[0110] In an example, the fuzzy TEC controller may include a parameter tuner to evaluate a cost factor associated with each of the plurality of fuzzy rules, the cost factor based at least in part on the amount of cumulative power consumed by the at least one TEC device and the at least one fan.

[0111] In an example, the fuzzy TEC controller may include inference logic to derive a fuzzy inference based on a weighted combination of the plurality of fuzzy outputs. In an example, the fuzzy TEC controller may include de-fuzzification logic to de-fuzzify at least one output of the inference logic.

[0112] In another example embodiment may be a method to control thermoelectric cooling, the method including: converting, using a thermoelectric cooling (TEC) controller, a current TEC level to obtain a first fuzzy fan level; converting, using the TEC controller, a current fan level to obtain a second fuzzy fan level; performing a fuzzy inference based on the first fuzzy fan level and the second fuzzy fan level; and determining a new TEC level based at least in part on the fuzzy inference.

[0113] In an example, the method may also include determining a new fan level based at least in part on the fuzzy inference.

[0114] In an example, the method may also include providing power to a TEC device based on the new TEC level, where the TEC device is to transfer heat from an electronic component to a heat sink.

[0115] In an example, the current fan level may correspond to a first pulse width modulated (PWM) duty cycle, and the current TEC level may correspond to a second PWM duty cycle.

[0116] In an example, performing the fuzzy inference may include evaluating a plurality of fuzzy rules. In an example, the method may also include determining a cost factor for each of the plurality of fuzzy rules. In an example, the method may also include de-fuzzifying at least one output of the plurality of fuzzy rules.

[0117] In another example embodiment may be a communication device arranged to perform the method described above.

[0118] In another example embodiment may be at least one machine readable medium comprising a plurality of instructions that in response to being executed on a computing device, cause the computing device to carry out the method described above.

[0119] In another example embodiment may be an apparatus for processing instructions, configured to perform the method described above.

[0120] In another example embodiment may be an apparatus comprising means for performing the method described above.

[0121] References throughout this specification to “one embodiment” or “an embodiment” mean that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one implementation encompassed within the present invention. Thus, appearances of the phrase “one embodiment” or “in an embodiment” are not necessarily referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be instituted in other suitable forms other than the particular embodiment illustrated and all such forms may be encompassed within the claims of the present application.

[0122] While the present invention has been described with respect to a limited number of embodiments for the sake of illustration, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.

What is claimed is:

1. A processor comprising:

a fuzzy thermoelectric cooling (TEC) controller to:

obtain a current TEC level associated with the processor;
obtain a current fan power level associated with the processor;

fuzzify the current TEC level to obtain a first fuzzy fan level;

fuzzify the current fan power level to obtain a second fuzzy fan level;

determine a new TEC power level based at least in part on the first fuzzy fan level, the second fuzzy fan level, and a plurality of fuzzy rules; and

provide the new TEC power level to a TEC device associated with the processor, wherein the TEC device is to transfer heat from the processor to a heat sink.

2. The processor of claim 1, wherein the fuzzy TEC controller is further to calculate a new fan power level based at least in part on the first fuzzy fan level, the second fuzzy fan level, and the plurality of fuzzy rules.

3. The processor of claim 2, wherein the fuzzy TEC controller is further to provide the new fan power level to at least one cooling fan providing an air flow to the heat sink.

4. The processor of claim 1, wherein the fuzzy TEC controller is further to obtain a current temperature associated with the processor.

5. The processor of claim 4, wherein the fuzzy TEC controller is to determine the new TEC power level using the current temperature.

6. The processor of claim 1, wherein the fuzzy TEC controller is further to:

evaluate, using at least the first fuzzy fan level and the second fuzzy fan level, the plurality of fuzzy rules to obtain a plurality of fuzzy outputs; and

perform a fuzzy inference using the plurality of fuzzy outputs.

7. The processor of claim 6, wherein the fuzzy TEC controller is further to de-fuzzify each of the plurality of fuzzy outputs to obtain quantities.

8. The processor of claim 1, wherein the fuzzy TEC controller is to determine the new TEC power level based at least in part on reducing a cost factor associated with each of the plurality of fuzzy rules.

9. The processor of claim 8, wherein the cost factor associated with each of the plurality of fuzzy rules is based at least in part on an amount of power consumed by a fan and an amount of power consumed by the TEC device.

10. The processor of claim 9, wherein the cost factor associated with each of the plurality of fuzzy rules is further based at least in part on an amount of power associated with heat leakage in the TEC device.

11. The processor of claim 1, wherein the fuzzy TEC controller is to determine the new TEC power level based at least in part on reducing a prediction error associated with each of the plurality of fuzzy rules.

- 12.** A system comprising:
a processor comprising:
at least one core to execute instructions;
a fuzzy thermoelectric cooling (TEC) controller to:
fuzzify a current TEC level to obtain a first fuzzy fan level;
fuzzify a current fan power level to obtain a second fuzzy fan level;
evaluate, using at least the first fuzzy fan level and the second fuzzy fan level, a plurality of fuzzy rules to obtain a plurality of fuzzy outputs;
determine a new TEC power level based at least in part on the plurality of fuzzy outputs.
a heat sink;
at least one TEC device to transfer heat from the processor to the heat sink based on the new TEC power level; and
a dynamic random access memory (DRAM) coupled to the processor.
- 13.** The system of claim **12**, further comprising:
at least one fan providing an air flow to the heat sink.
- 14.** The system of claim **13**, the fuzzy TEC controller comprising:
a parameter tuner to evaluate a cost factor associated with each of the plurality of fuzzy rules, the cost factor based at least in part on the amount of cumulative power consumed by the at least one TEC device and the at least one fan.
- 15.** The system of claim **12**, the fuzzy TEC controller comprising:
inference logic to derive a fuzzy inference based on a weighted combination of the plurality of fuzzy outputs.
- 16.** The system of claim **15**, the fuzzy TEC controller comprising:
de-fuzzification logic to de-fuzzify at least one output of the inference logic.
- 17.** A method, comprising:
converting, using a thermoelectric cooling (TEC) controller, a current TEC level to obtain a first fuzzy fan level;
converting, using the TEC controller, a current fan level to obtain a second fuzzy fan level;
performing a fuzzy inference based on the first fuzzy fan level and the second fuzzy fan level; and
determining a new TEC level based at least in part on the fuzzy inference.
- 18.** The method of claim **17**, further comprising determining a new fan level based at least in part on the fuzzy inference.
- 19.** The method of claim **17**, further comprising providing power to a TEC device based on the new TEC level, wherein the TEC device is to transfer heat from an electronic component to a heat sink.
- 20.** The method of claim **17**, wherein the current fan level corresponds to a first pulse width modulated (PWM) duty cycle, and the current TEC level corresponds to a second PWM duty cycle.
- * * * * *



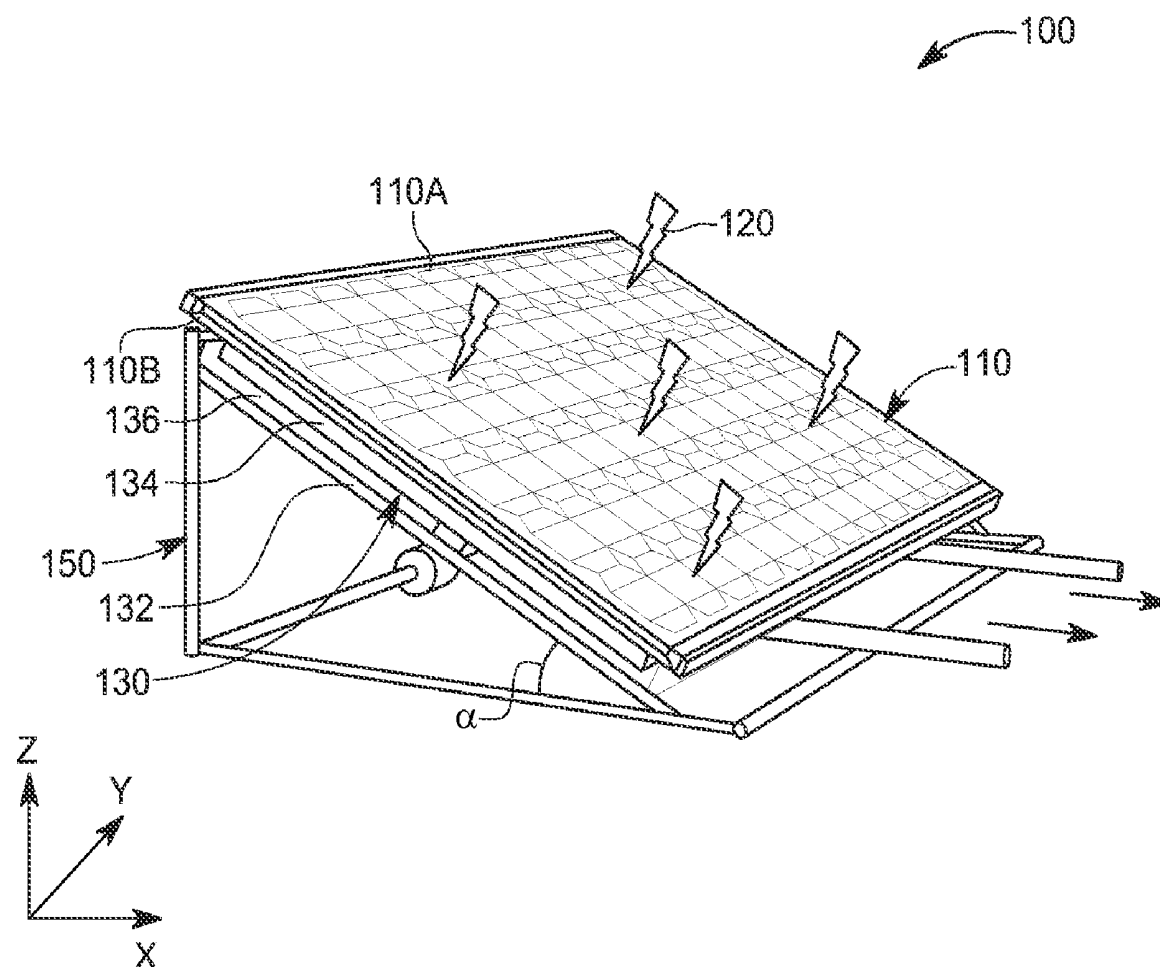
US 20210359644A1

(19) **United States**(12) **Patent Application Publication**
WANG et al.(10) **Pub. No.: US 2021/0359644 A1**(43) **Pub. Date: Nov. 18, 2021**(54) **SYSTEM AND METHOD FOR COOLING
PHOTOVOLTAIC PANEL WITH
ATMOSPHERIC WATER****Publication Classification**(51) **Int. Cl.**
H02S 40/42 (2006.01)(52) **U.S. Cl.**
CPC **H02S 40/425** (2014.12)(71) Applicant: **KING ABDULLAH UNIVERSITY
OF SCIENCE AND TECHNOLOGY,**
Thuwal (SA)(72) Inventors: **Peng WANG,** Thuwal (SA); **Renyuan
LI,** Thuwal (SA); **Yifeng SHI,** Thuwal
(SA)(57) **ABSTRACT**(21) Appl. No.: **17/287,300**(22) PCT Filed: **Sep. 17, 2019**(86) PCT No.: **PCT/IB2019/057828**

§ 371 (c)(1),

(2) Date: **Apr. 21, 2021****Related U.S. Application Data**(60) Provisional application No. 62/767,646, filed on Nov.
15, 2018.

An integrated photovoltaic (PV) panel-water sorption layer system that includes a PV panel having a front face that is configured to receive solar light for generating electrical current, and a back face that is opposite to the front face; and an atmospheric water harvesting device attached to the back face of the PV panel. The atmospheric water harvesting device is configured to cool down the PV panel by evaporating absorbed atmospheric water based on heat received from the PV panel.



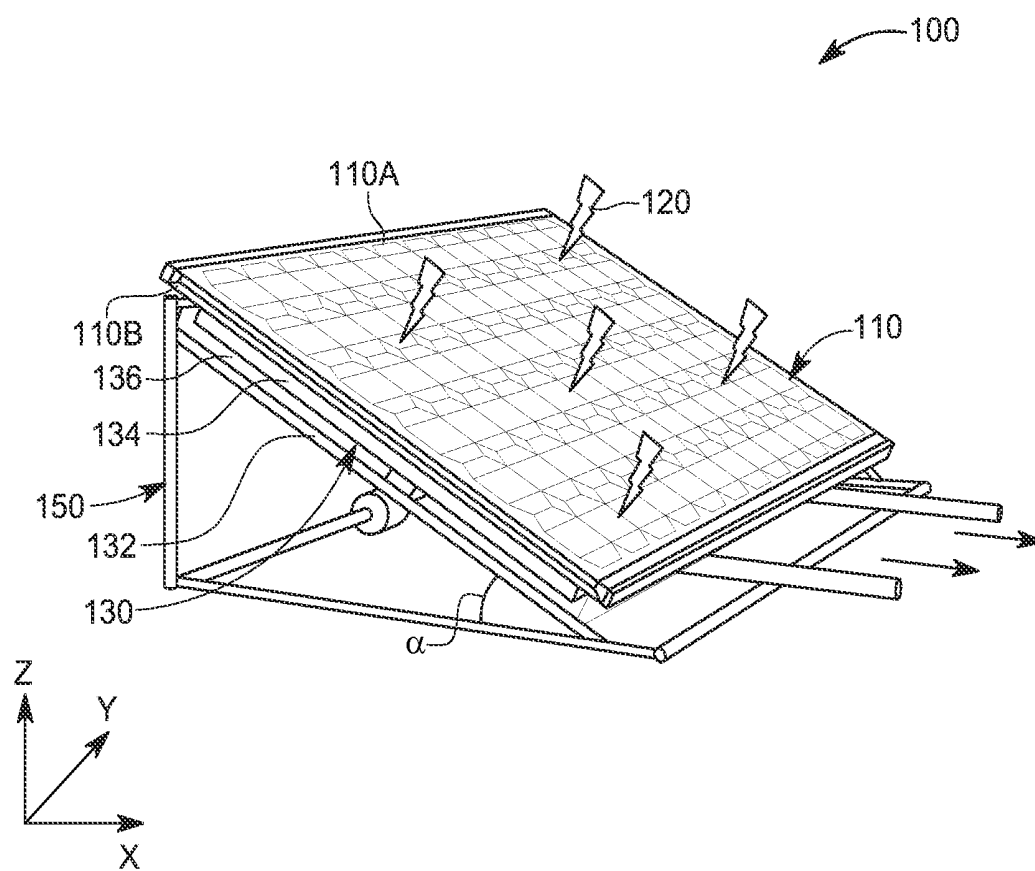


FIG. 1

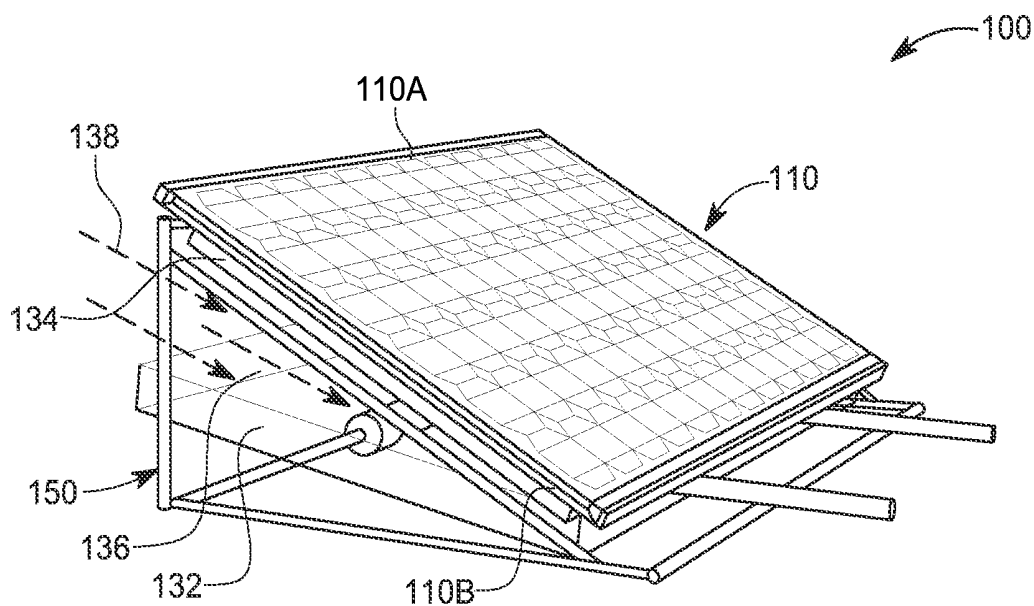


FIG. 2A

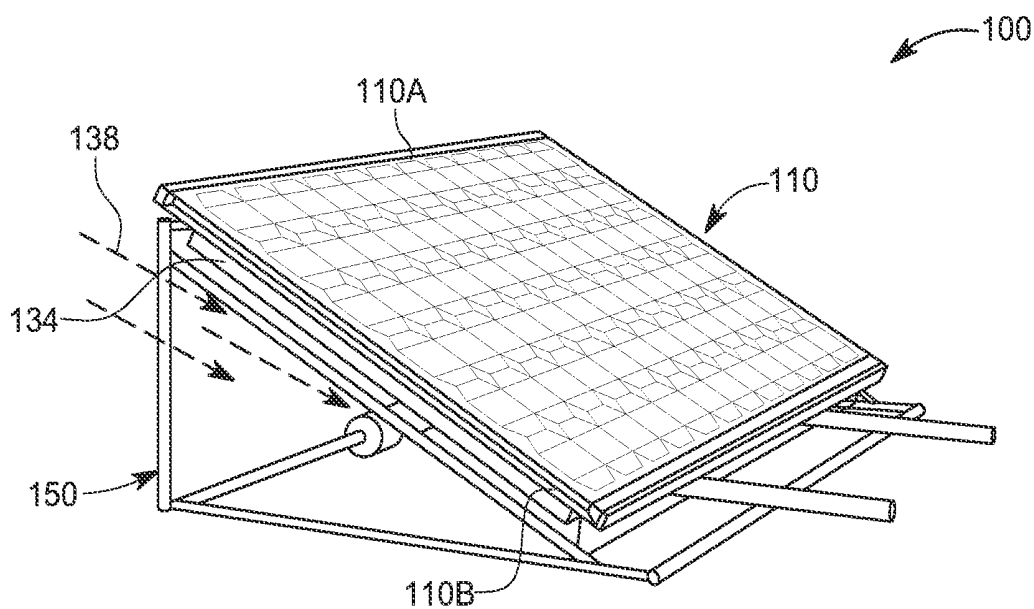


FIG. 2B

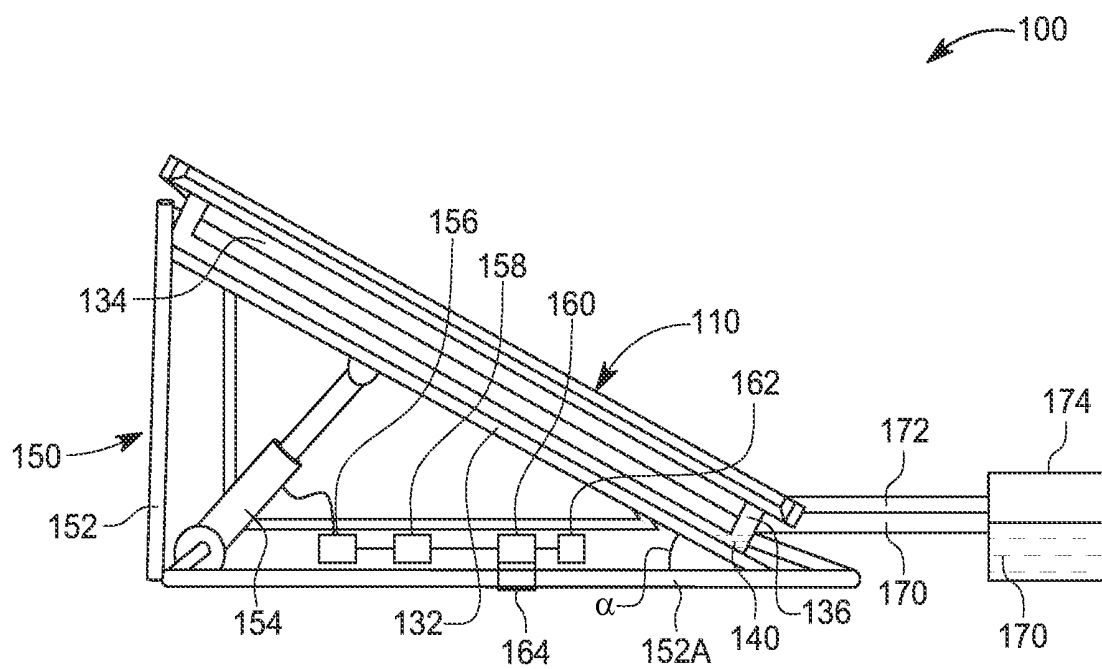


FIG. 3

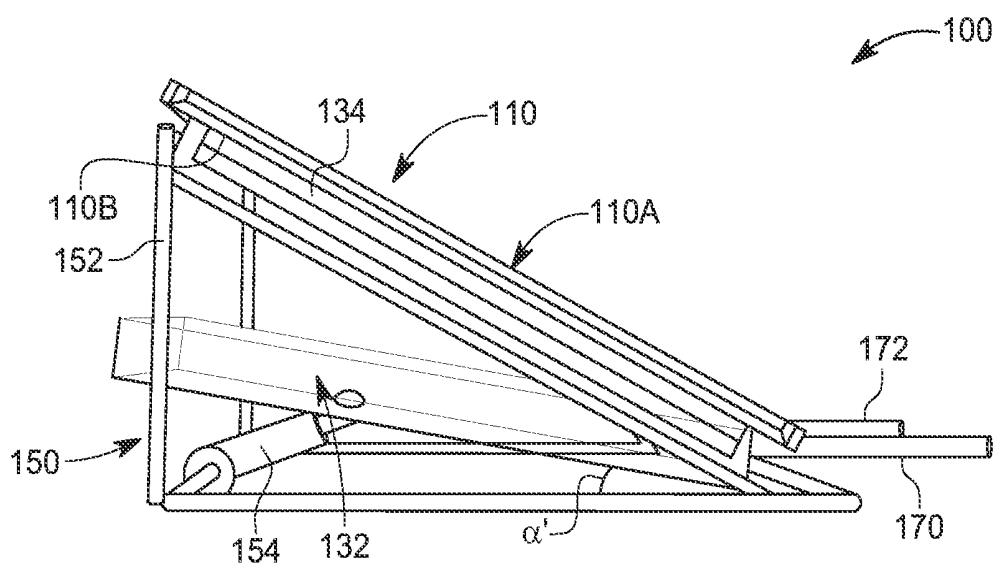


FIG. 4

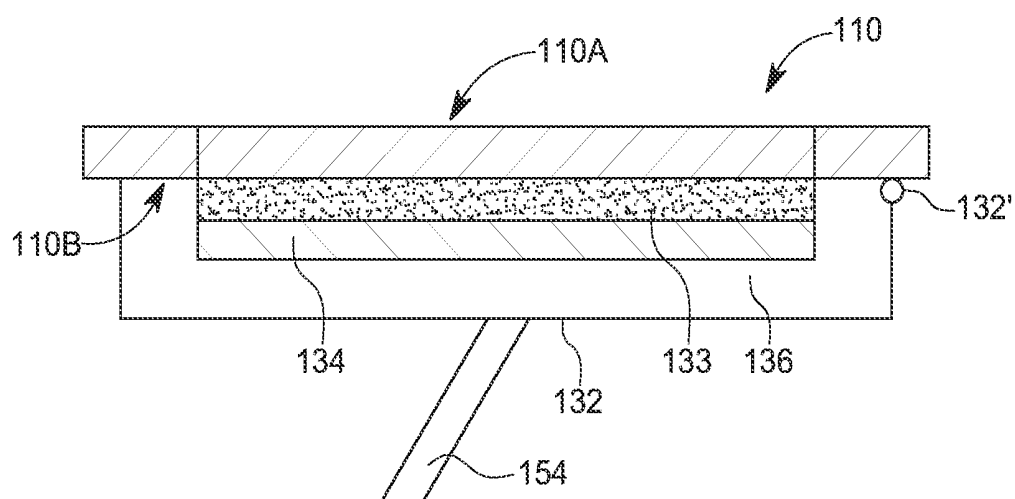


FIG. 5

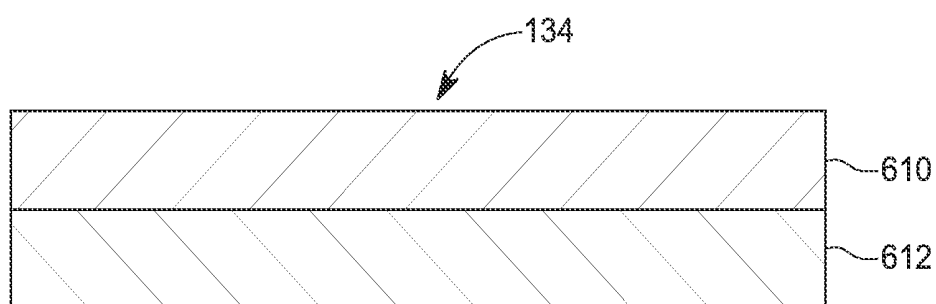


FIG. 6

Hydrous state formula	Anhydrous state formula
$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	FeSO_4
$\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$	Li_2SO_4
$\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$	Na_2CO_3
$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$	Na_2SO_4
$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$	CuCl_2
$(\text{CH}_3\text{COO})_2\text{Ni} \cdot 4\text{H}_2\text{O}$	$(\text{CH}_3\text{COO})_2\text{Ni}$
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	CuSO_4
$\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$	MgSO_4

FIG. 7

Chemical formula	IUPAC Name
LiCl	Lithium chloride
CaCl ₂	Calcium chloride
MgCl ₂	Magnesium chloride
ZnCl ₂	Zink chloride
FeCl ₃	Iron (III) chloride
Zn(NO ₃) ₂	Zink nitrate
Cu(NO ₃) ₂	Copper (II) nitrate
Ni(NO ₃) ₂	Nickel (II) nitrate
Mn(NO ₃) ₂	Manganese (II) nitrate

FIG. 8

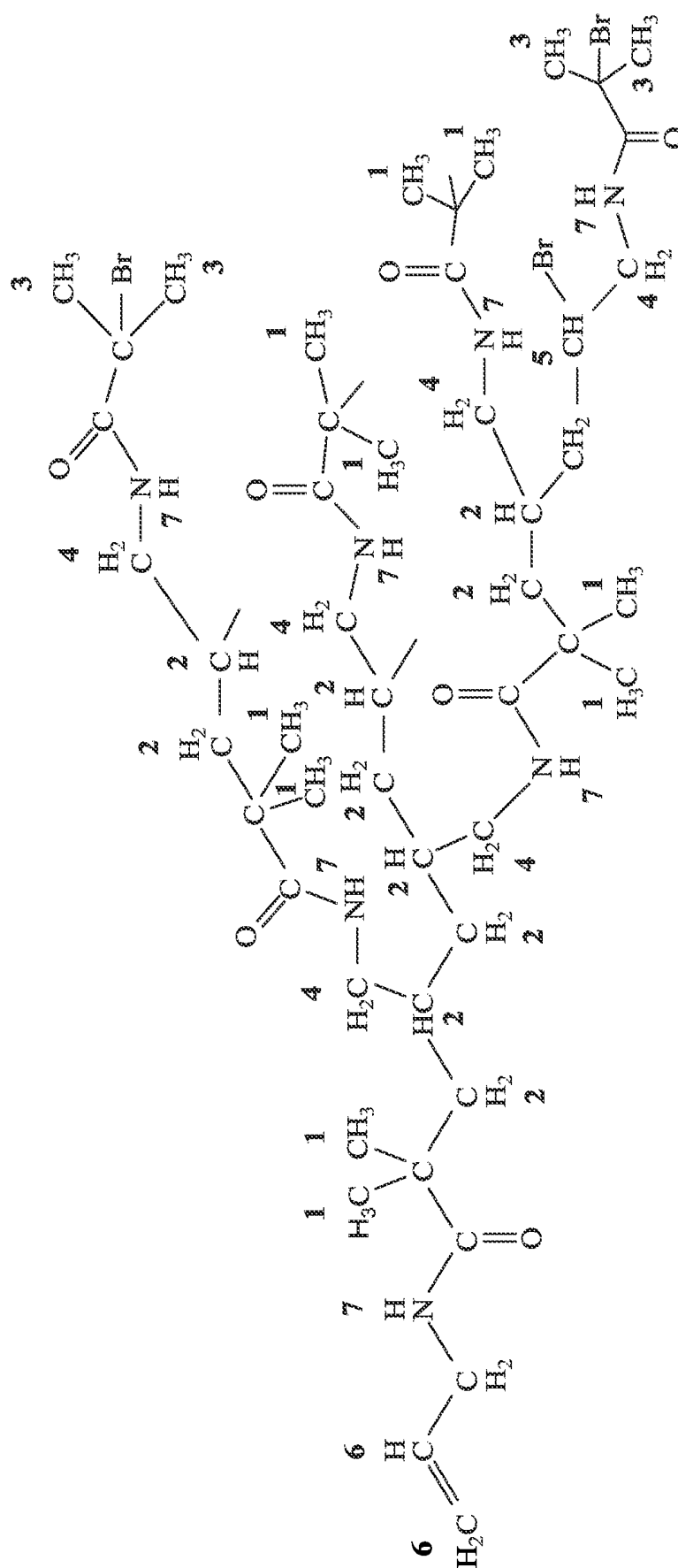


FIG. 9A

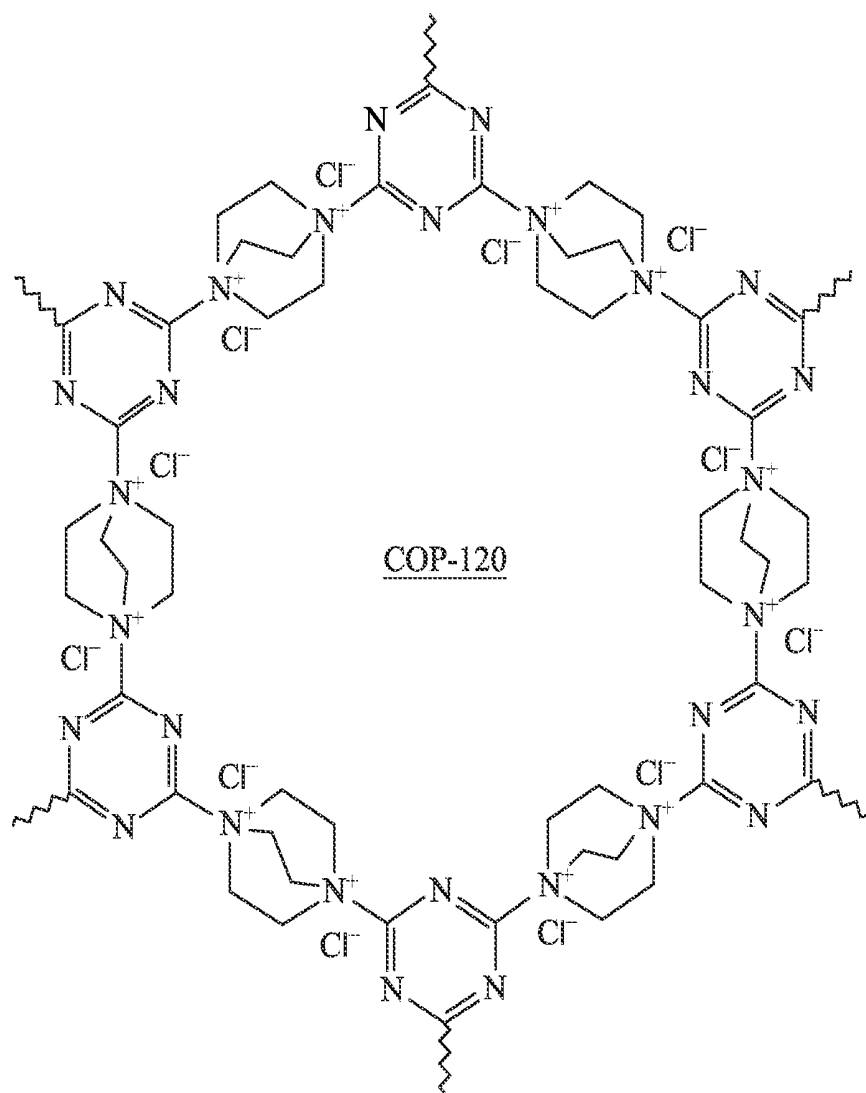


FIG. 9B

Polymer	Abbreviation
Poly(acrylic acid)	PAA
Poly(vinyl pyrrolidone)	PVP
Poly(acrylamide)	PAM
Poly(ethylene oxide)	PEO
Poly(vinyl methyl ether)	PVME
Poly(vinyl alcohol)	PVA
Hydroxypropylcellulose	HPC
Hydroxyethylcellulose	HEC
Poly(2-hydroxyethyl vinyl ether)	PHEVE
Poly(N-isopropylacrylamide)	PNIPAM

FIG. 10

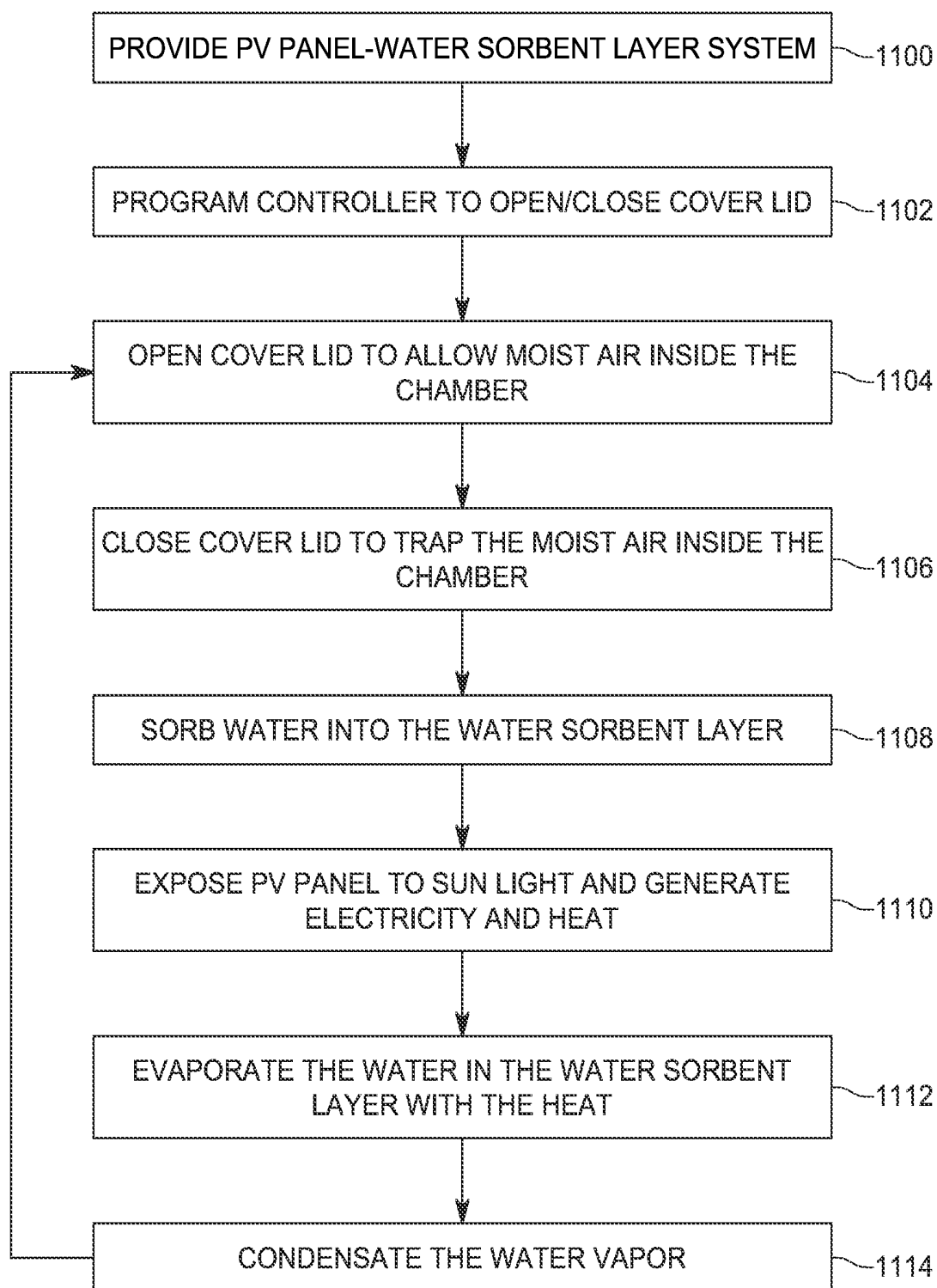


FIG. 11

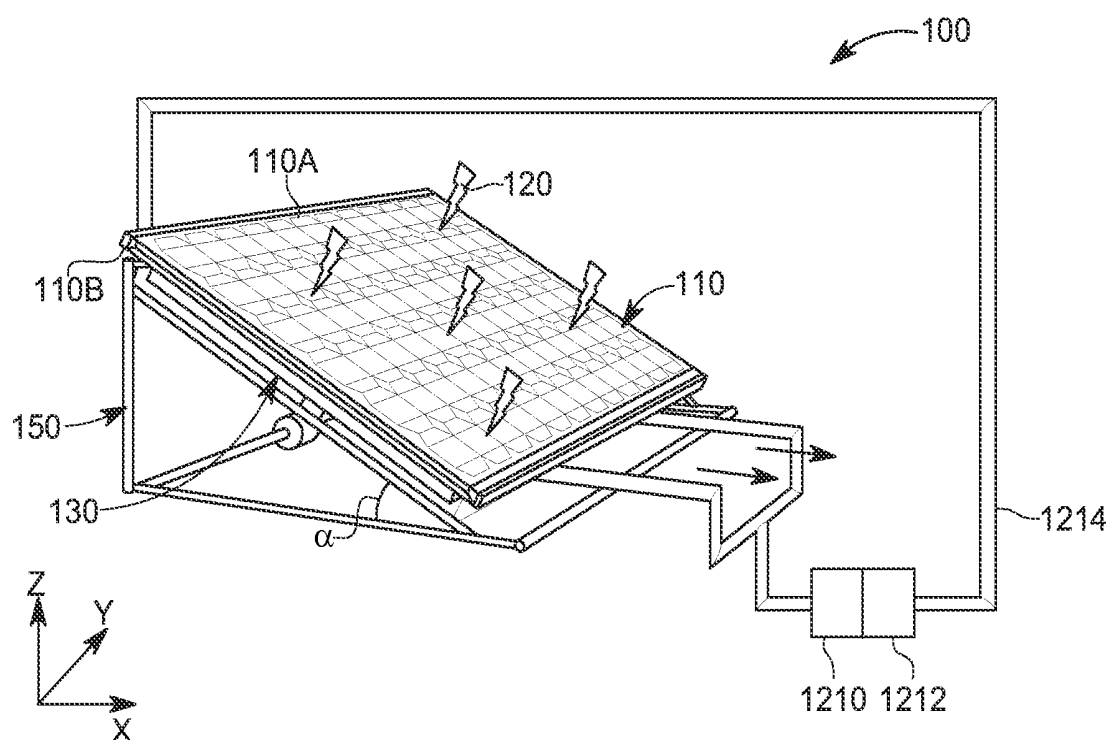


FIG. 12A

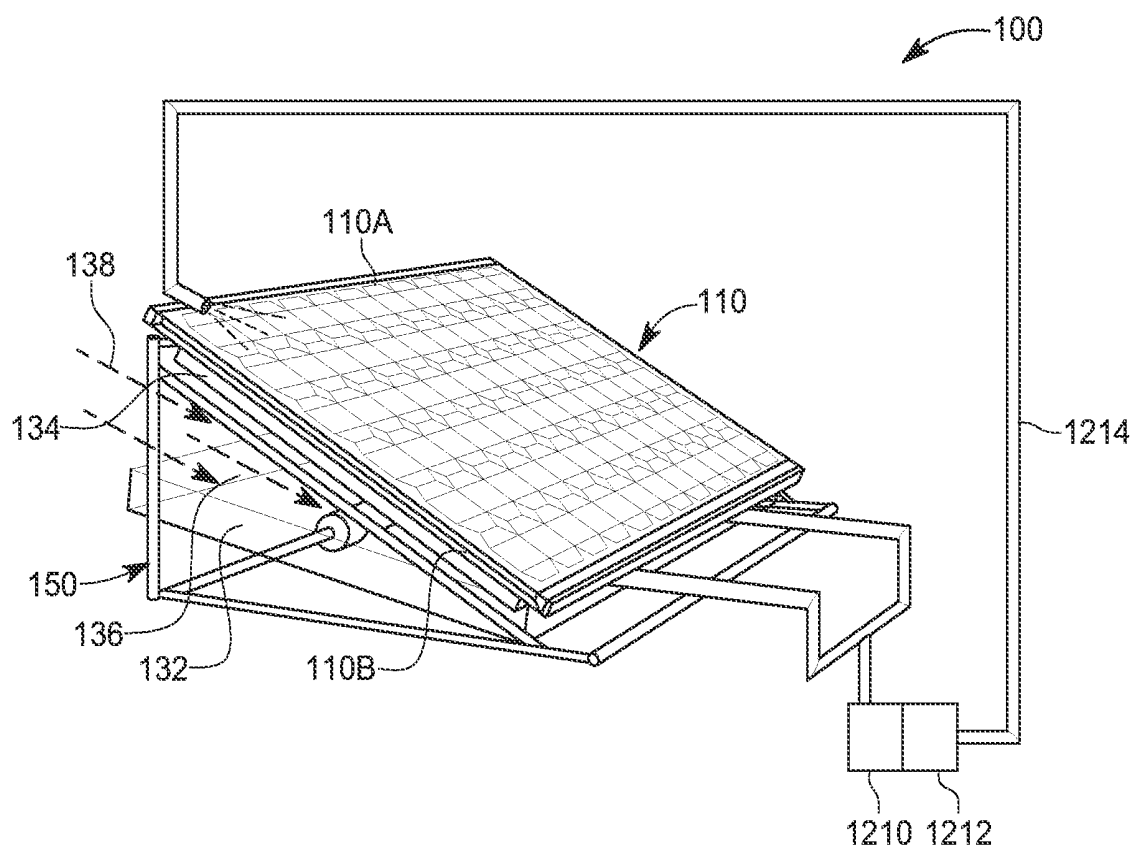


FIG. 12B

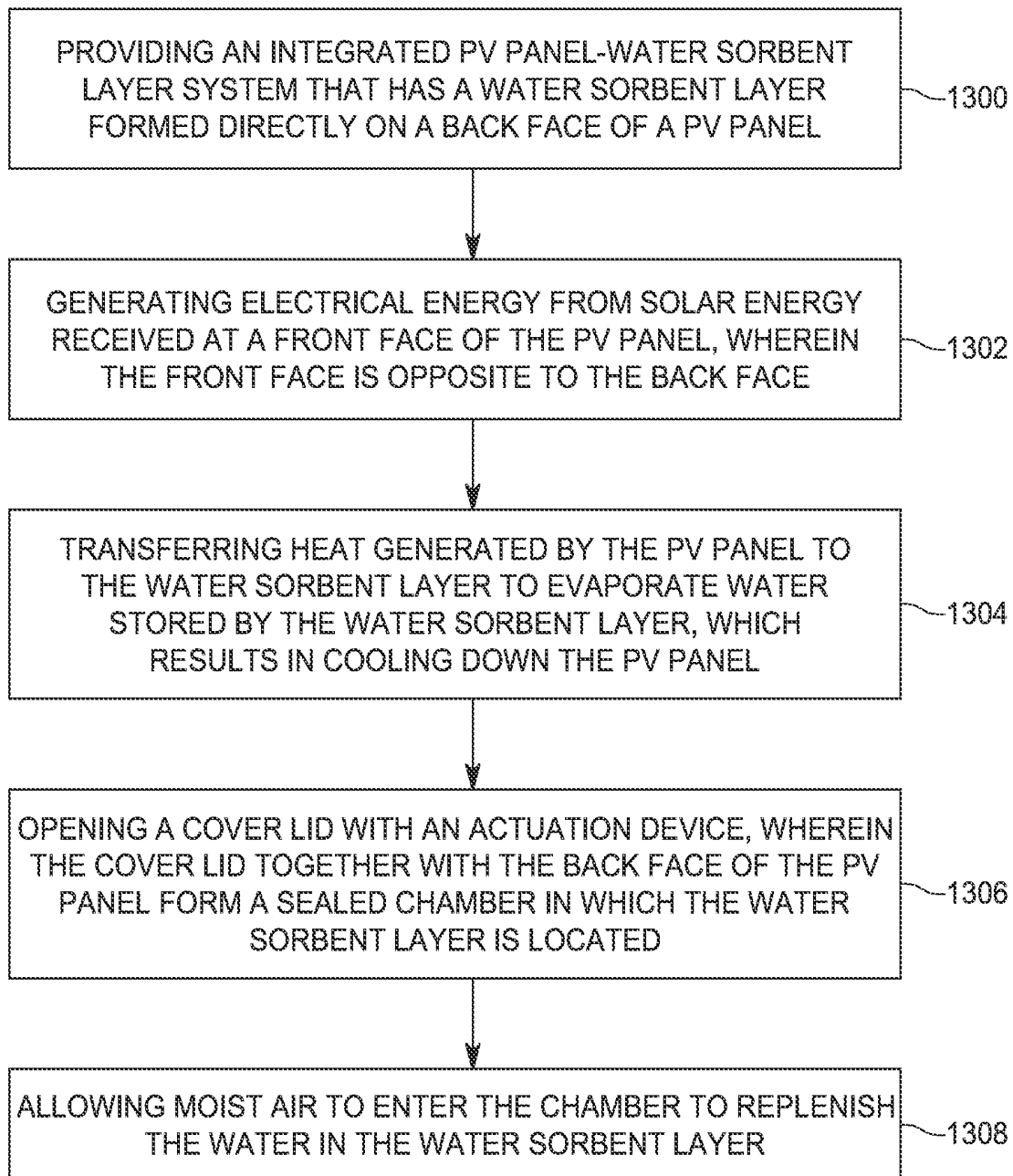


FIG. 13

SYSTEM AND METHOD FOR COOLING PHOTOVOLTAIC PANEL WITH ATMOSPHERIC WATER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 62/767,646, filed on Nov. 15, 2018, entitled "A METHOD FOR PHOTOVOLTAIC (PV) PANEL COOLING ASSISTED BY ATMOSPHERIC WATER HARVESTING MATERIAL," the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

Technical Field

[0002] Embodiments of the subject matter disclosed herein generally relate to a system and method for cooling a photovoltaic (PV) panel with water harvested from the atmosphere, and more particularly, to a system that absorbs moist air from the air, evaporates the water to cool down the PV panel, and generates fresh water by condensing the water vapor.

Discussion of the Background

[0003] A solar panel (also referred to herein as a solar cell or photovoltaic panel (PV panel)) usually absorbs 80% to 95% of the energy from the sunlight that is incident on its surface. From this energy, only about 6% to 25% of the absorbed solar energy is converted to electricity. The rest of the absorbed solar energy is converted to heat, which undesirably increases the temperature of the PV panel. In addition, as many PV panels are placed in regions of high sun activity, these regions also tend to be hot, i.e., to show high temperatures during the day. When the temperature of a PV panel increases due to any kind of heat, its energy efficiency decreases. In addition, the high temperature of the PV panel also degrades its lifetime. Thus, effective cooling of the PV panel is desired for the solar power plants.

[0004] There are two types of cooling technics that have been adopted in the industry. A first cooling technique is the active cooling, which mainly uses cold water or wind flow as a coolant for removing the ambient heat. The advantage of this active cooling approach is the high-efficiency of the heat dissipation from the PV panel surface. However, the active cooling approach requires a complicated engineering design and needs extra energy to power up the condenser and the re-flux coolant that are part of the cooling system. In addition, this approach uses fresh water, which might be scarce in the region where the PV panels are installed.

[0005] The second cooling approach is the passive cooling. The passive cooling by a large-scale heat sink array has been previously reported in the literature. The advantage of the heat-sink based passive cooling process is that it uses less energy and needs a less complicated structure than the active cooling system. However, a disadvantage of this approach is that it entails large heat sink areas.

[0006] Thus, engineering simple, inexpensive, and effective strategies for PV panel cooling is highly sought after.

BRIEF SUMMARY OF THE INVENTION

[0007] According to an embodiment, there is an integrated photovoltaic (PV) panel-water sorption layer system that

includes a PV panel having a front face that is configured to receive solar light for generating electrical current, and a back face that is opposite to the front face, and an atmospheric water harvesting device attached to the back face of the PV panel. The atmospheric water harvesting device is configured to cool down the PV panel by evaporating absorbed atmospheric water based on heat received from the PV panel.

[0008] According to another embodiment, there is an integrated photovoltaic (PV) panel-water sorption layer system that includes a PV panel having a front face that is configured to receive solar light for generating electrical current, and a back face that is opposite to the front face, a water sorption layer formed directly on the back face of the PV panel, a cover lid that together with the back face of the PV panel form a sealed chamber, wherein the water sorption layer is located inside the sealed chamber, and an actuation device connected to the cover lid. The actuation device is configured to move the cover lid to unseal the chamber so that ambient air enters inside the chamber.

[0009] According to still another embodiment, there is a method for cooling down a photovoltaic (PV) panel with water harvested from atmosphere. The method includes providing an integrated photovoltaic (PV) panel-water sorption layer system that has a water sorption layer formed directly on a back face of a PV panel, generating electrical energy from solar energy received at a front face of the PV panel, wherein the front face is opposite to the back face, transferring heat generated by the PV panel to the water sorption layer to evaporate water stored by the water sorption layer, which results in cooling down the PV panel, opening a cover lid with an actuation device, wherein the cover lid together with the back face of the PV panel form a sealed chamber in which the water sorption layer is located, and allowing moist air to enter the chamber to replenish the water in the water sorption layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0011] FIG. 1 is a schematic diagram of an integrated PV panel-water sorption layer system that cools a PV panel with water harvested from the ambient;

[0012] FIG. 2A is a schematic diagram of the integrated PV panel-water sorption layer system showing an open cover lid for allowing the ambient air to enter inside a chamber where a water sorption layer is located and FIG. 2B shows the same but without a cover lid;

[0013] FIG. 3 is a side view of the integrated PV panel-water sorption layer system that shows other components;

[0014] FIG. 4 is also a side view of the integrated PV panel-water sorption layer system that shows an actuation mechanism for moving the cover lid;

[0015] FIG. 5 schematically illustrates the location of various layers that form the integrated PV panel-water sorption layer system;

[0016] FIG. 6 schematically illustrates the water sorption layer of the integrated PV panel-water sorption layer system;

[0017] FIGS. 7 to 10 show various possible components of the water sorption layer;

[0018] FIG. 11 is a flowchart of a method for cooling down the PV panel, of the integrated PV panel-water sorption layer system, with water harvested from the ambient air; [0019] FIGS. 12A and 12B illustrate a variation of the integrated PV panel-water sorption layer system, in which the fresh water generated in the chamber is reused; and [0020] FIG. 13 is a flowchart of another method for cooling down the PV panel of the integrated PV panel-water sorption layer system with water harvested from the ambient air.

DETAILED DESCRIPTION OF THE INVENTION

[0021] The following description of the embodiments refers to the accompanying drawings. The same reference numbers in different drawings identify the same or similar elements. The following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims. The following embodiments are discussed, for simplicity, with regard to a system that uses a hydraulic activated cover lid for forming a closed chamber in which moist air is trapped and heated. However, the embodiments to be discussed next are not limited to a hydraulic activated cover lid, but may be applied to any types of a moving cover lid.

[0022] Reference throughout the specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described in connection with an embodiment is included in at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrases “in one embodiment” or “in an embodiment” in various places throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments.

[0023] According to an embodiment, a water sorption layer is used as a new passive cooling component for PV panel cooling. This water sorbent cooling layer can be directly attached to a back face of the PV panel. In one application, the water sorbent cooling layer is attached to a highly thermally conductive layer and this layer is directly attached to the back face of the PV panel. The water sorbent cooling layer is configured to capture/store water from the ambient air during night or other periods when the PV panel is not operating, and to cool down the PV panel during day time, by evaporating the sorbed water. Note that a water sorbent material is a material that is configured to absorb or adsorb water from the ambient. If the water takes up the volume of this layer, the process is called absorption. However, if the water attaches to the surface of the layer, then the process is called adsorption. The term “sorbent” is used herein to cover absorption, adsorption, and both absorption and adsorption.

[0024] One or more advantages of various embodiments of this system include, but is not limited to: (1) it is an all-in-one system integrating water harvesting and PV panel cooling; (2) it has a reliable engineering design; (3) it works in the absence of any open water source; and (4) the harvested atmospheric water can be collected as fresh water for other uses, such as solar panel dust removal and/or top surface cooling.

[0025] More details about this water sorption layer and how the layer is integrated with a PV panel are now discussed with regard to the figures. FIG. 1 shows an

integrated PV panel-water sorption layer system 100, which is called herein atmospheric water cooled PV panel system. The atmospheric water cooled PV panel system 100 includes a PV panel 110, which has a front face 110A that is configured to receive solar light 120, and an atmospheric water harvesting device 130, which is directly attached to a back face 110B of the PV panel 110. Note that the front face 110A of the PV panel is opposite to the back face 110B. The atmospheric water cooled PV panel system 100 further includes a support mechanism 150, which is configured to support both the PV panel 110 and the water harvesting device 130. The PV panel is supported by the support mechanism 150 with a certain non-zero angle α relative to a horizontal plane defined by the axes X and Y in the figure. The support mechanism 150 may include various piping as discussed later.

[0026] The support mechanism 150 is configured to open and close a cover lid 132 of the water harvesting device 130, to allow moist air to contact a water sorption layer 134, as illustrated in FIG. 2A. In this embodiment, the water sorption layer 134 is shown being directly attached to the back face 110B of the PV panel 110. However, as previously discussed, a highly thermally conductive layer can be sandwiched between the back face of the PV panel and the water sorption layer. The cover lid 132 is configured to encapsulate the water sorption layer 134 when in the closed position, as shown in FIG. 1. The cover lid 132 and the back face 110B of the PV panel 110 form a chamber 136, which is sealed from the ambient when closed. In one application, the cover lid and the back face of the PV panel fully encapsulate the water sorption layer, i.e., these two elements fully define the chamber. However, as shown in FIG. 2A, when the cover lid 132 is in the open position, the chamber 136 is open to the ambient so that the moist air 138 can enter inside the chamber. Note that in one embodiment, it is possible, as shown in FIG. 2B, to have the harvesting device 130 with no cover lid 132, so that moist air can continuously be absorbed by the water sorption layer 134.

[0027] FIG. 3 shows a side view of the atmospheric water cooled PV panel system 100. The cover lid 132 is shown in the closed position, forming the chamber 136 with the back face 110B of the PV panel 110. FIG. 3 also shows that while a frame 152 (for example, metallic frame) holds the PV panel 110 at the angle α relative to a horizontal part (base 152A) of the frame 150, an actuation device 154, which is also part of the support mechanism 150, is attached between the base 152A and the back face 110B of the panel 110, and is configured to move the cover lid 132 between the closed position shown in FIG. 3 and the open position shown in FIG. 4. The actuation device 156 may be a hydraulic device as shown in FIGS. 3 and 4 having a hydraulic arm. One skilled in the art would understand that the actuation device 156 may also be implemented as a non-hydraulic device, for example, as an electric motor and a corresponding arm.

[0028] FIG. 3 also shows a pump 156 that is configured to pump air or another fluid, for example, from a storage container 158, into the hydraulic arm to open and close the cover lid 132. In one embodiment, a controller 160 automatically determines when to close and open the cover lid 132 and instructs accordingly the hydraulic arm to move the cover lid. The controller 160, which may be implemented as a computing device or processor, may be connected to a

power source **162**, for example, a battery. In one embodiment, the battery may be charged by electricity generated by the PV panel **110**.

[0029] In still another embodiment, the controller **160** may include a light sensor or an internal clock **164**, which may be used for determining when to close or open the cover lid. For example, if a light sensor **164** is provided with the controller **160**, then the controller may be programmed to keep the cover lid **132** closed during the day time, so that water evaporates inside the chamber **136** and cools the PV panel **110**, and to keep the cover lid open during the night time, so that the moist ambient air **138** enters the chamber to replenish the water in the water sorption layer. In another implementation, if the internal clock is used instead of the light sensor, the controller may be programmed to open the cover lid during the night time and close the cover lid during the day time based on the time provided by the internal clock. Those skilled in the art would recognize that the controller may be programmed based on other criteria for opening and closing the cover lid, for example, based on weather considerations, humidity inside the chamber, etc.

[0030] In the embodiment illustrated in FIG. 3, one or more pipes **170** and **172** may be connected to the bottom of the chamber **136**, so that the condensed water **140**, formed inside the chamber **136**, can be collected at a container **174**, that is attached to the one or more pipes **170** and **172**. The condensed water **140** is fresh water in this case and it is obtained by condensing on the cover lid the water vapor formed as a consequence of evaporating the atmospheric water sorbed by the water sorption layer **134**, due to the heat generated by the back face of the PV panel.

[0031] Note that the cover lid **132** moves due to the actuation device **154** from the closed position, which is described by the first angle α , to the open position, which is described by a second angle α' . In one embodiment, both angles α and α' are non-zero angles and they are different from each other.

[0032] The water sorption layer **134** can be directly attached to the back face **1106** of the PV panel **110** as shown in FIGS. 1-4. However, in one embodiment, as illustrated in FIG. 5, a heat conducting layer **133** may be placed between the back face **1106** of the PV panel **110** and the water sorption layer **134** so that the heat conducting layer **133** is directly sandwiched between the back face of the PV panel and the water sorption layer. These layers can be attached to each other by known methods, for example, direct bonding with a resin or glue, or can be mechanically attached to each other with clamps, screws, or other similar means. FIG. 5 also shows the chamber **136** formed between the back face **1106** of the PV panel **110** and the cover lid **132**. A hinge **132'** or similar mechanism may be formed between the PV panel **110** and the cover lid **132** to allow the cover lid to open and close when actuated by the actuation mechanism **154**. In one embodiment, the hinge **132'** may be part of the support device **150**.

[0033] The water sorption layer **134** may be implemented, in one embodiment, as a combination of two components: (1) a water vapor sorbent sublayer **610**, and (2) a substrate/matrix sublayer **612**, as illustrated in FIG. 6. The water vapor sorbent sublayer **610** may include one or more of the following materials: (a) conventional solid-state porous materials; (b) anhydrate/hydrate salt couples; (c) deliquescent salts, (d) hygroscopic polymers, and (e) ionic liquids.

[0034] The conventional solid-state porous materials (a) may include, but are not limited to: activated carbon, metal-organic-framework (MOF), zeolite, silica gel, mesoporous silica/carbon, clay, etc. The anhydrate/hydrate salt couples (b) are inexpensive and commercially available. They can absorb water vapor in air through a hydration reaction. FIG. 7 shows a group of examples of hydrous/anhydrous couples that can be used for the water vapor sorbent sublayer **610**. The deliquescent salt (c) can dissolve itself into water when exposed to a humid ambient air and is capable of capturing large amount of water. FIG. 8 shows several examples of such deliquescent salts that can be used for the water vapor sorbent sublayer **610**. The hygroscopic polymers (d) may be obtained by tuning their chemical composition and structures. The hygroscopic polymers can be used as water vapor sorbent under certain circumstances. FIGS. 9A and 9B shows two example of hygroscopic polymer structures. The ionic liquids (e) have been investigated as liquid desiccants in several fields. The advantage of the ionic liquids is their low corrosion to metals. The above mentioned water vapor sorbents can be mixed in any combination for tuning the water sorption layer's performance, depending on application scenario (humidity of the ambient air, temperature of the ambient air, etc.).

[0035] The substrates/matrix sublayer **612** is needed when the water vapor sorption sublayer **610** includes materials that are powdery substances or a liquid. In one embodiment, the matrix sublayer **612** may include (a) polymeric hydrogels, and/or (b) metallic/organic/inorganic-nonmetallic sponges/foams to hold the powdery or liquid water vapor sorbents. The polymeric hydrogels (a) are configured to hold large quantities of water by volume expansion, and also they are capable of maintaining their solid-state structure. FIG. 10 shows a group of polymeric hydrogels that can be used in this embodiment. Furthermore, the hydrogel material can be made from a mixture of the polymers shown in FIG. 10.

[0036] The metallic/organic/inorganic-nonmetallic sponges/foams (b) have a porous structure that can hold large amounts of powdery water vapor sorbents and provides large amount of sorption sites. They also have outstanding heat transfer capabilities due to the conductivity of ceramics, metal and carbon fiber that may present. The metallic/organic/inorganic-nonmetallic sponges/foams are inexpensive materials, and one example of such material is the glass fibers.

[0037] A method for cooling a PV panel with water harvested from the atmosphere is now discussed with regard to FIG. 11. The integrated PV panel-water sorption layer system **100** can include as the water vapor sorption sublayer any material or combination of materials discussed above. In addition, the integrated PV panel-water sorption layer system **100** can include as the substrate/matrix sublayer **612** any material or combination of materials discussed above. The method starts in step **1100** by providing the integrated PV panel-water sorption layer system **100** at a location where there is a sunlight during the day. In step **1102**, a controller **160** of the system **100** is programmed to open and close the cover lid **132** when a given condition is taking place. In one embodiment, the condition is related to a time of the day, i.e., close the cover lid during the day time and open the cover lid during the night time. Other conditions may be used. In step **1104**, the cover lid is opened and moist air **138** enters inside the chamber **136**, which is defined by the cover lid **132**. In step **1106**, the cover lid is closed so that the moist air

138 is trapped inside the chamber **136**. Note that steps **1104** and **1106** may be automatically implemented by the controller **160**.

[0038] Because the water sorption layer **134** is enclosed by the cover lid **132**, water from the moist air **138** is sorbed in step **1108** by this layer. In step **1110**, the panel PV **110** is exposed to the sun light and generates electricity. At the same time, the panel PV generates heat, which is transferred through its back face **110B** to the water sorption layer **134**. In step **1112**, the heat transferred from the PV panel **110** is used by the water sorption layer **134** to evaporate the water sorbed from the moist air, and thus, to reduce a temperature of the PV panel. During this process, the heat from the PV panel is effectively used as latent heat to evaporate the water in the water sorption layer and create the water vapor. In step **1114**, the water vapor contacts the walls of the cover lid and condensate, forming fresh water **140**, which may be collected outside the system **100**, as shown in FIG. 3. The process then returns to step **1104**, so that more moist air is allowed into the chamber and the following steps are repeated. The controller **160** controls how many times a day the cover lid opens and closes. In one application, the cover lid is opened only during the night and closed during the entire day. If the controller is connected either to sensors that can anticipate the weather or to a weather service provider, the controller can also activate the actuation device **154** to open the cover lid during the day, for example, if there are rainy conditions or there is no sun.

[0039] While the figures show only one integrated PV panel-water sorption layer system **100**, those skilled in the art would understand that all the PV panels of a power production plant may be modified to have the features shown in the figures. In other words, any PV panel may be retrofitted with the atmospheric water harvesting device **130** for cooling the PV panel with water harvested from atmosphere.

[0040] In one embodiment, as illustrated in FIGS. 12A and 12B, the fresh water **140** generated inside the chamber **136** is collected outside the system **100**, into a water container **1210**, and then, pumped with a pump **1212** along a conduit **1214** back to the chamber **136** (see FIG. 12A). If this configuration is implemented, then the conduit **1214** is configured to deliver the water directly to the water sorption layer **134**. In this case, the conduit **1214** may be provided, for example, with a shower head to spray the water directly onto the water sorption layer **134**. The pump **1212** may be controlled by controller **160** and may be supplied with electricity directly from the PV panel **110** or the power source **162** (see FIG. 3). Even if the fresh water **140** is recirculated, the controller still opens and closes the cover lid **132**, as illustrated in FIG. 12B. In a variation of this embodiment, the conduit **1214** may be configured to spray the fresh water **140** directly onto the front surface **110A** of the PV panel **110**, for cleaning it.

[0041] A method for cooling down a PV panel with water harvested from atmosphere is now discussed with regard to FIG. 13. The method includes a step **1300** of providing an integrated PV panel-water sorption layer system that has a water sorption layer formed directly on a back face of a PV panel, a step **1302** of generating electrical energy from solar energy received at a front face of the PV panel, wherein the front face is opposite to the back face, a step **1304** of transferring heat generated by the PV panel to the water sorption layer to evaporate water stored by the water sorp-

tion layer, which results in cooling down the PV panel, a step **1306** of opening a cover lid with an actuation device, wherein the cover lid together with the back face of the PV panel form a sealed chamber in which the water sorption layer is located, and a step **1308** of allowing moist air to enter the chamber to replenish the water in the water sorption layer.

[0042] The method may further include a step of closing the cover lid to seal the chamber and to restart the water evaporation process, and/or actuating an actuation device to close and open the cover lid. The evaporated water may be collected as previously discussed for cleaning the surface of the PV panel, or it can be recirculated back to the water sorption layer. However, if the condensed water is not desired to be collected, it can be simply discharged outside the chamber, for example, through one or more pipes as shown in the figures.

[0043] The disclosed embodiments provide an integrated PV panel-water sorption layer system that cools down the PV panel with water harvested from the atmosphere. It should be understood that this description is not intended to limit the invention. On the contrary, the embodiments are intended to cover alternatives, modifications and equivalents, which are included in the spirit and scope of the invention as defined by the appended claims. Further, in the detailed description of the embodiments, numerous specific details are set forth in order to provide a comprehensive understanding of the claimed invention. However, one skilled in the art would understand that various embodiments may be practiced without such specific details.

[0044] Although the features and elements of the present embodiments are described in the embodiments in particular combinations, each feature or element can be used alone without the other features and elements of the embodiments or in various combinations with or without other features and elements disclosed herein.

[0045] This written description uses examples of the subject matter disclosed to enable any person skilled in the art to practice the same, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the subject matter is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims.

1. An integrated photovoltaic (PV) panel-water sorption layer system comprising:

- a PV panel having a front face that is configured to receive solar light for generating electrical current, and a back face that is opposite to the front face; and
- an atmospheric water harvesting device attached to the back face of the PV panel,

wherein the atmospheric water harvesting device is configured to cool down the PV panel by evaporating absorbed atmospheric water based on heat received from the PV panel.

2. The system of claim 1, wherein the atmospheric water harvesting device comprises:

- a water sorption layer formed directly on the back face of the PV panel; and
 - a cover lid that together with the back face of the PV panel form a sealed chamber,
- wherein the water sorption layer is placed in the sealed chamber.

3. The system of claim 2, further comprising:
an actuation device connected to the cover lid and configured to move the cover lid to unseal the chamber so that ambient air enters inside the chamber.
4. The system of claim 3, wherein the actuation device includes a hydraulic arm that moves the cover lid between an open position and a closed position.
5. The system of claim 4, wherein the chamber is unsealed in the open position and the chamber is sealed in the closed position.
6. The system of claim 3, wherein the ambient air enters the chamber in the open position, but not in the closed position.
7. The system of claim 2, wherein the water sorption layer includes a hydrogel configured to absorb or adsorb water.
8. The system of claim 2, wherein the water sorption layer includes a first water vapor sorption sublayer and a substrate sublayer that is configured to support the water vapor sorption sublayer.
9. The system of claim 8, wherein the water vapor sorption sublayer includes at least one of a solid-state porous material, anhydrate or hydrate salt couple, deliquescent salt, hygroscopic polymer and ionic liquid.
10. The system of claim 1, further comprising:
a water sorption layer formed directly on the back face of the PV panel; and
no cover lid that forms a sealed chamber together with the back face of the PV panel so that the water sorption layer is continuously open to atmosphere.
11. The system of claim 1, further comprising:
a cover lid that together with the back face of the PV panel form a sealed chamber, wherein the water sorption layer is placed in the sealed chamber;
a hydraulic device connected to the cover lid;
a controller that controls the hydraulic device to move the cover lid to unseal the chamber so that ambient air enters inside the chamber; and
a support device configured to hold the PV panel at a non-zero angle with the ground, and also to provide support to the hydraulic device and the controller.
12. The system of claim 11, further comprising:
one or more pipes connected to the chamber and configured to direct the fresh water from the chamber to outside of the system.
13. The system of claim 12, further comprising:
a conduit configured to direct the fresh water from the outside the system either back to the chamber, onto the water sorption layer, or onto the front face of the PV panel.
14. An integrated photovoltaic (PV) panel-water sorption layer system comprising:
a PV panel having a front face that is configured to receive solar light for generating electrical current, and a back face that is opposite to the front face;
a water sorption layer formed directly on the back face of the PV panel;
a cover lid that together with the back face of the PV panel form a sealed chamber, wherein the water sorption layer is located inside the sealed chamber; and
an actuation device connected to the cover lid,
wherein the actuation device is configured to move the cover lid to unseal the chamber so that ambient air enters inside the chamber.
15. The system of claim 14, wherein the water sorption layer includes a hydrogel configured to absorb or adsorb water from the ambient air.
16. The system of claim 14, wherein the water sorption layer includes a first water vapor sorption sublayer and a substrate sublayer that is configured to support the water vapor sorption sublayer.
17. The system of claim 14, wherein the water vapor sorption sublayer includes at least one of a solid-state porous material, anhydrate or hydrate salt couple, deliquescent salt, hygroscopic polymer and ionic liquid.
18. A method for cooling down a photovoltaic (PV) panel with water harvested from atmosphere, the method comprising:
providing an integrated photovoltaic (PV) panel-water sorption layer system that has a water sorption layer formed directly on a back face of a PV panel;
generating electrical energy from solar energy received at a front face of the PV panel, wherein the front face is opposite to the back face;
transferring heat generated by the PV panel to the water sorption layer to evaporate water stored by the water sorption layer, which results in cooling down the PV panel;
opening a cover lid with an actuation device, wherein the cover lid together with the back face of the PV panel form a sealed chamber in which the water sorption layer is located; and
allowing moist air to enter the chamber to replenish the water in the water sorption layer.
19. The method of claim 18, further comprising:
closing the cover lid to seal the chamber and to restart the water evaporation process.
20. The method of claim 19, further comprising:
actuating an actuation device to close or open the cover lid.

* * * * *

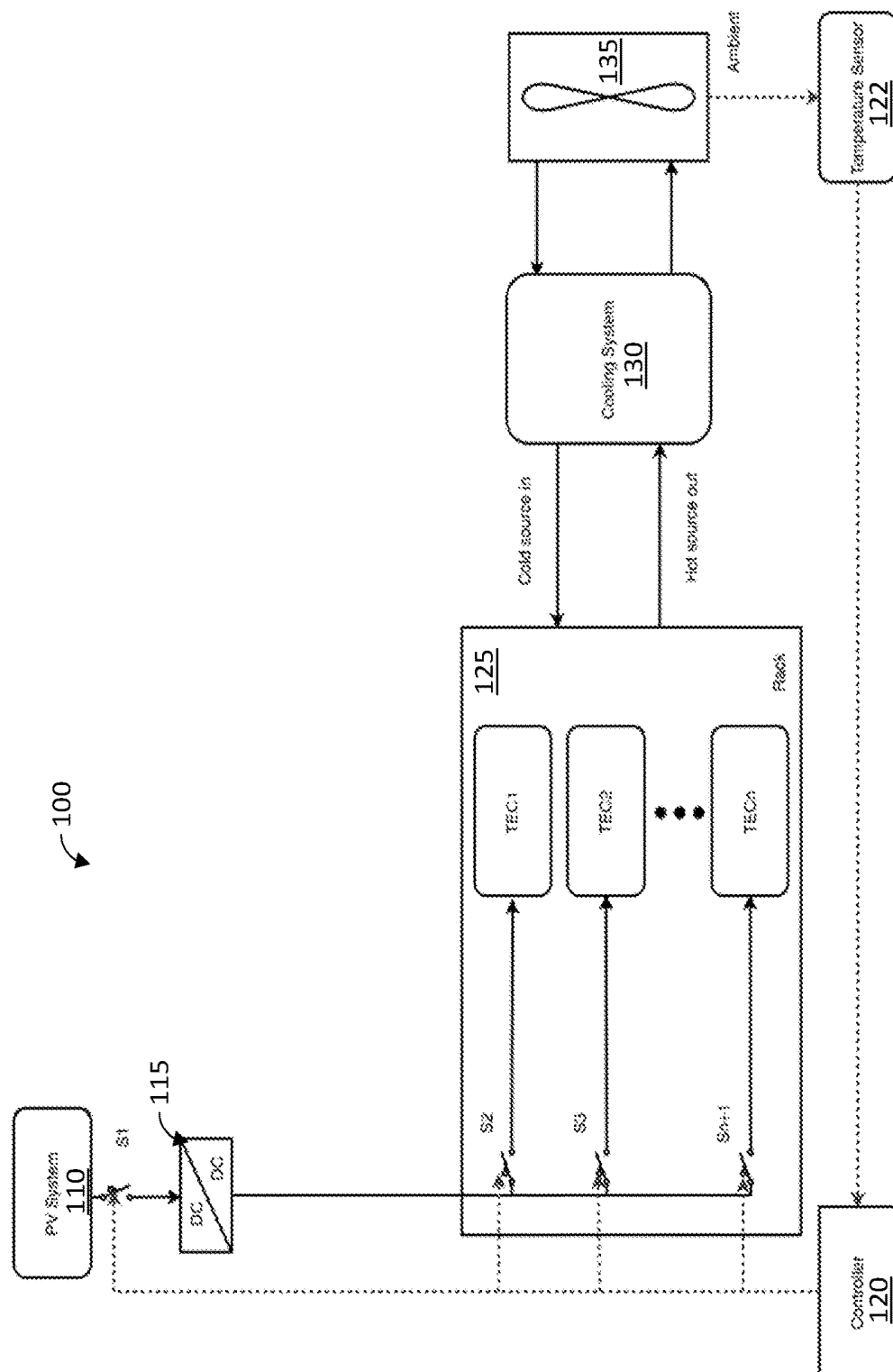


Figure 1

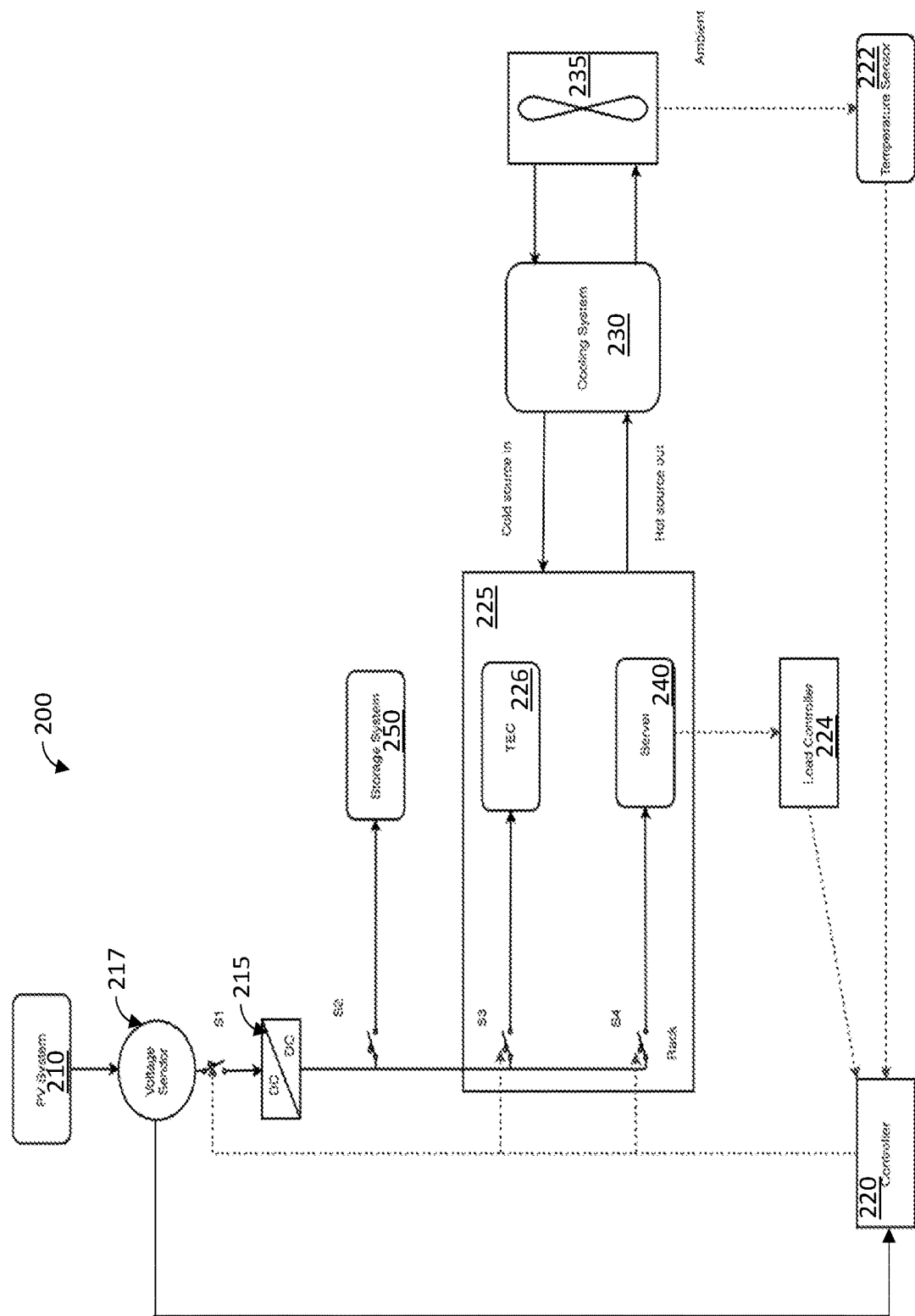


Figure 2

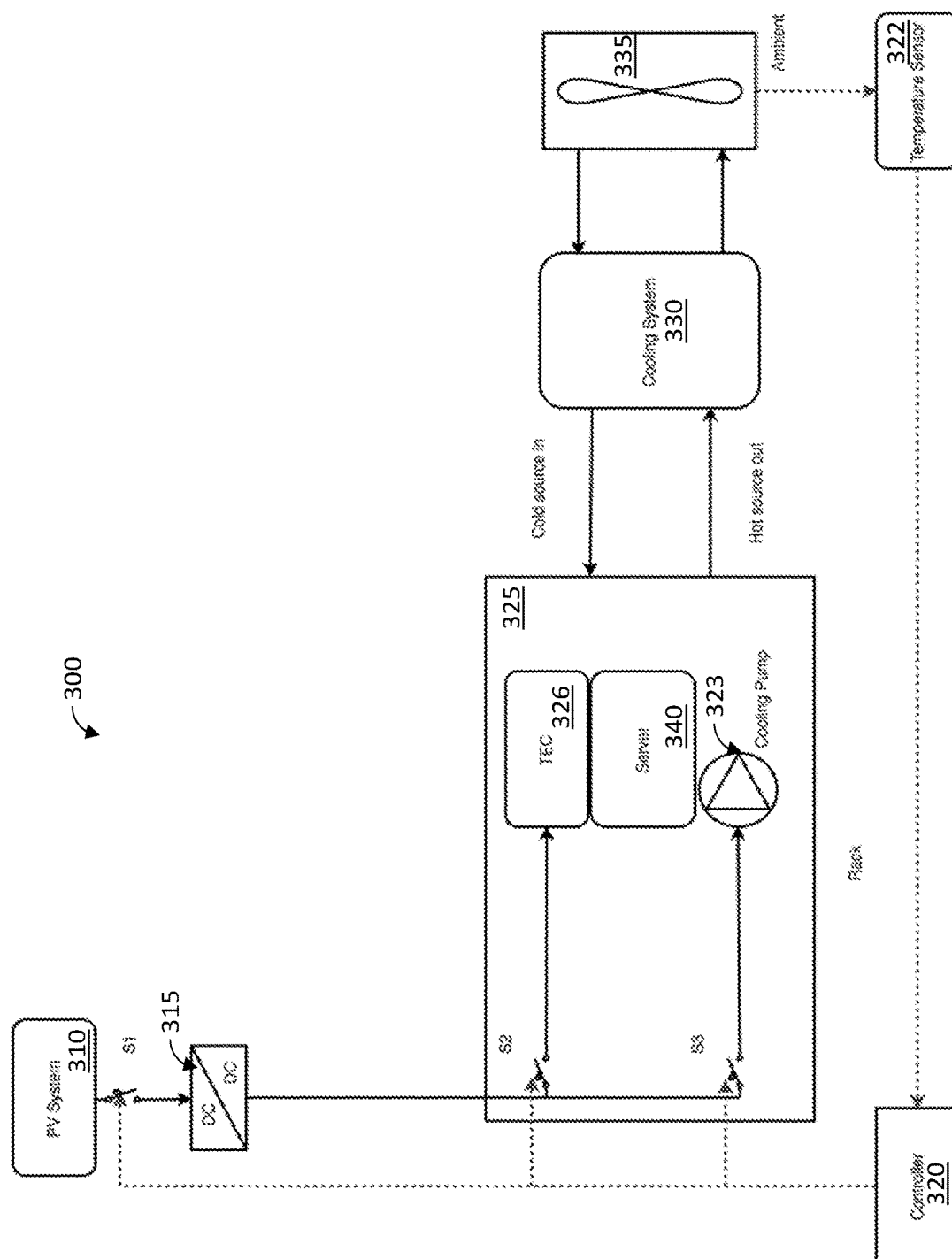


Figure 3

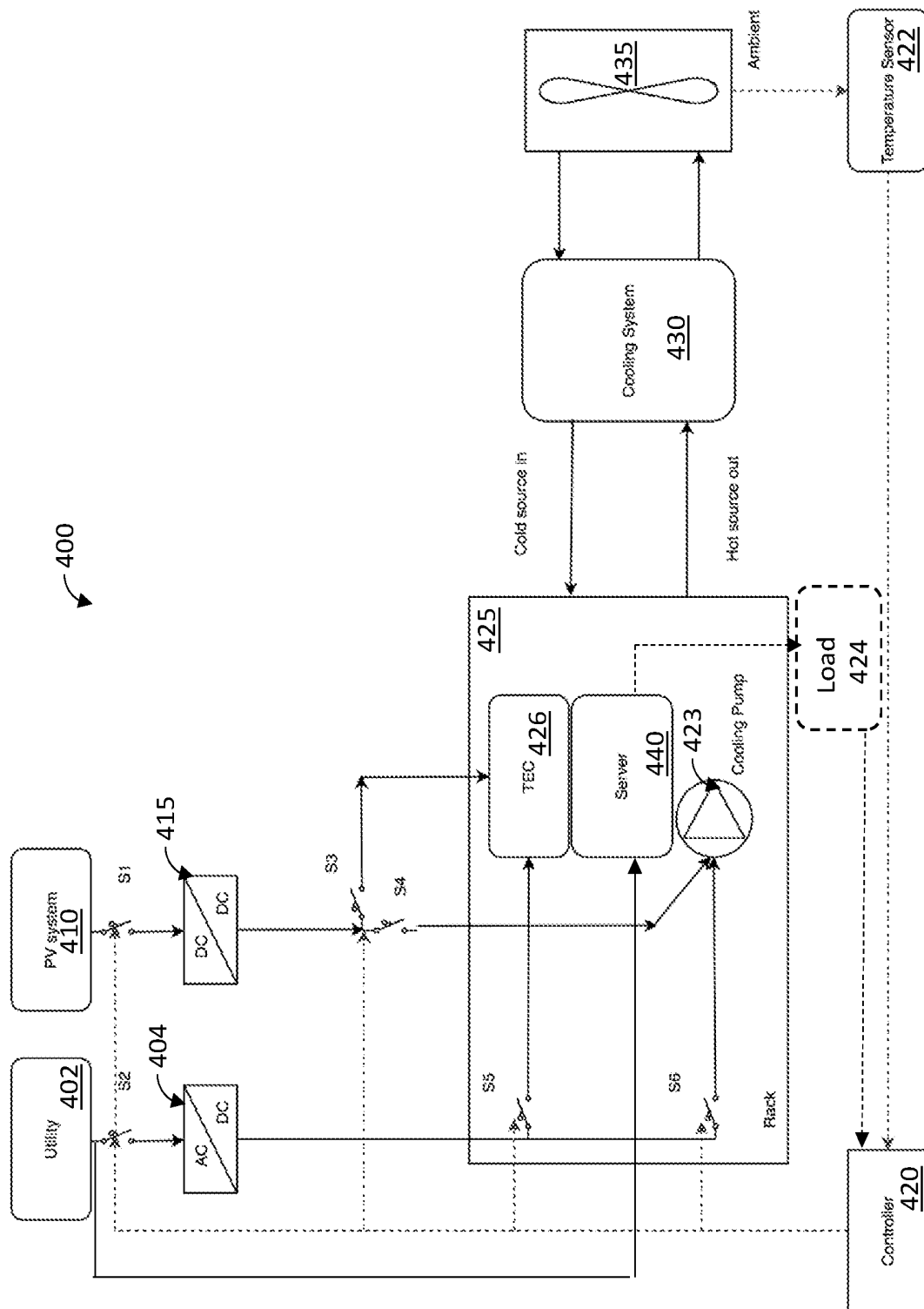


Figure 4

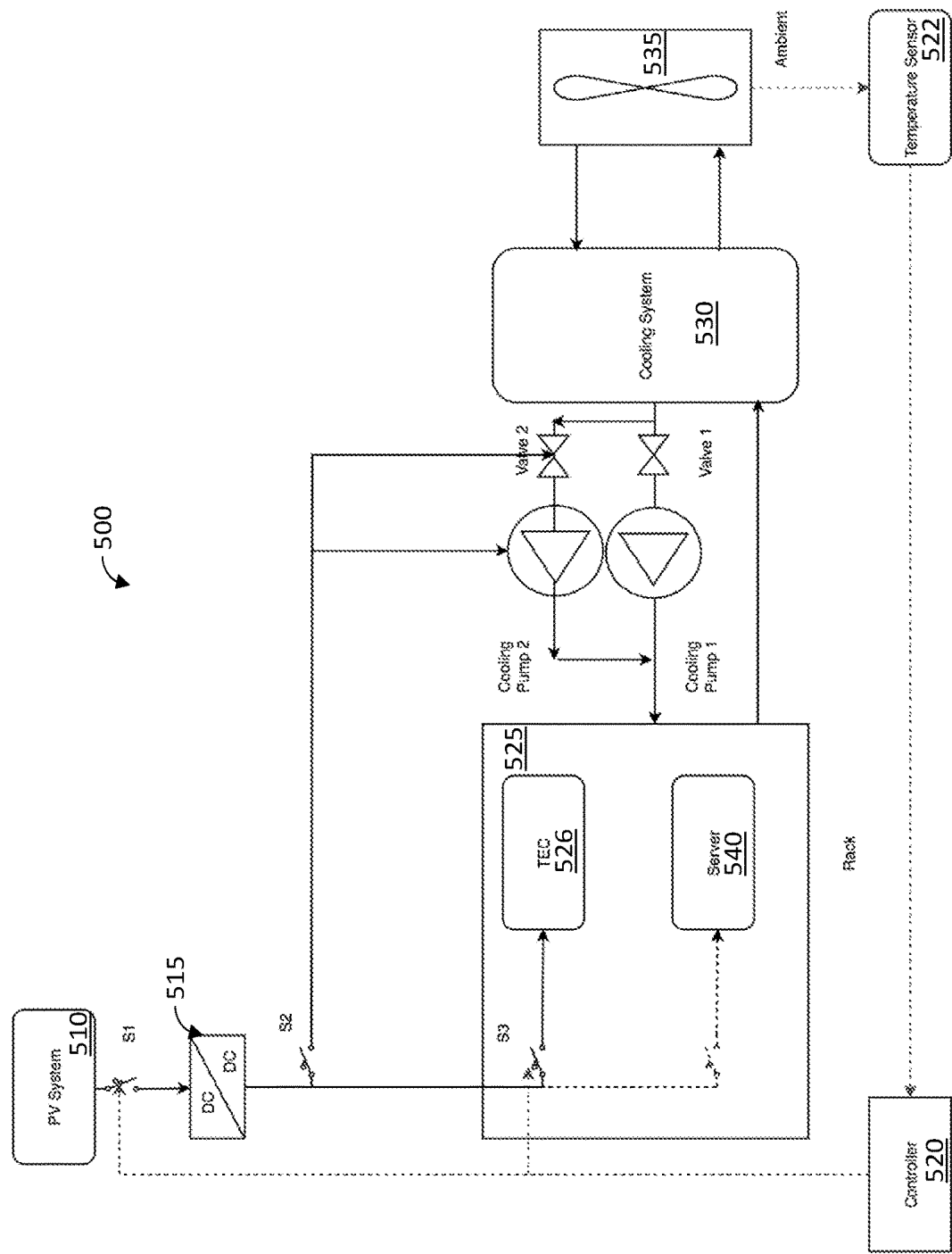


Figure 5

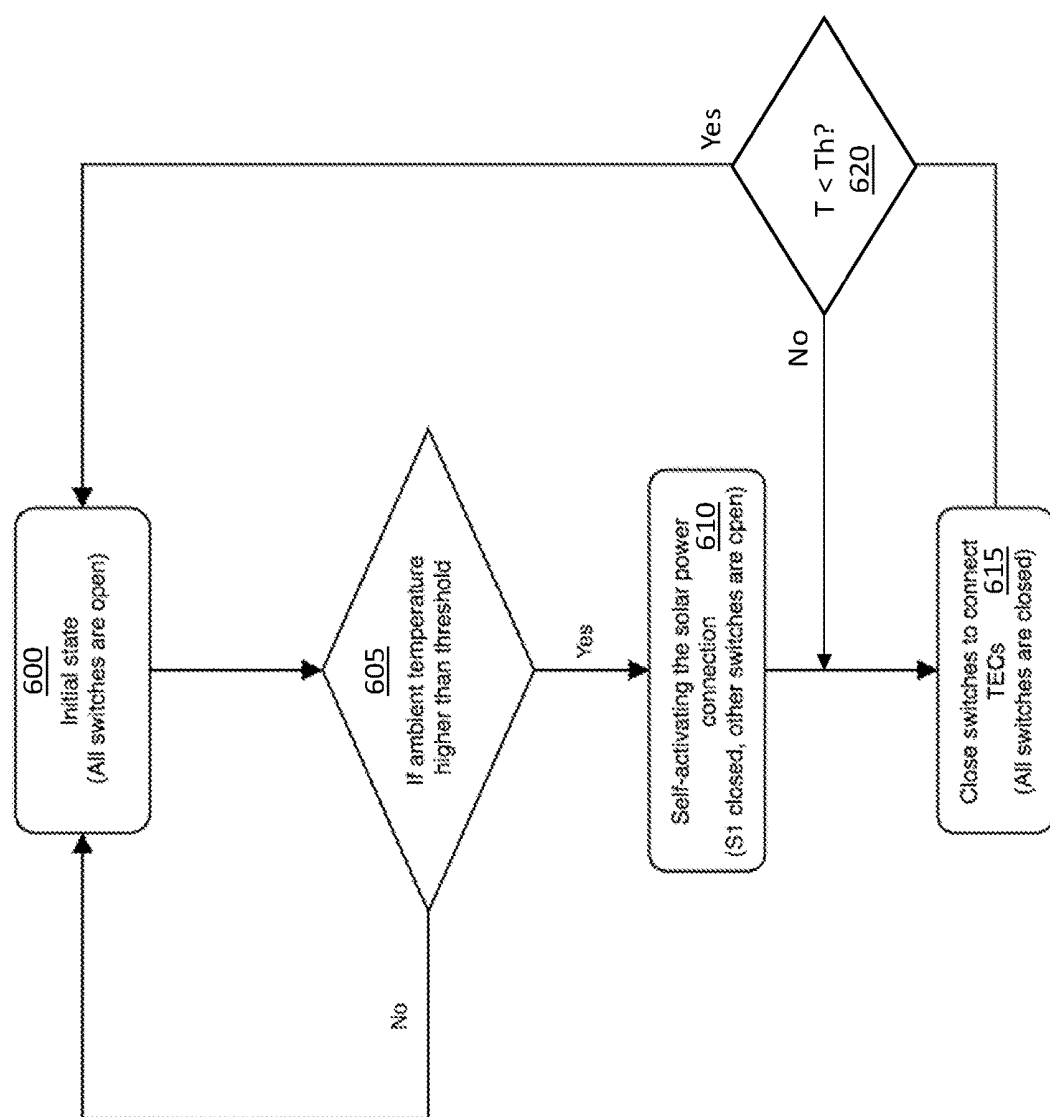


Figure 6

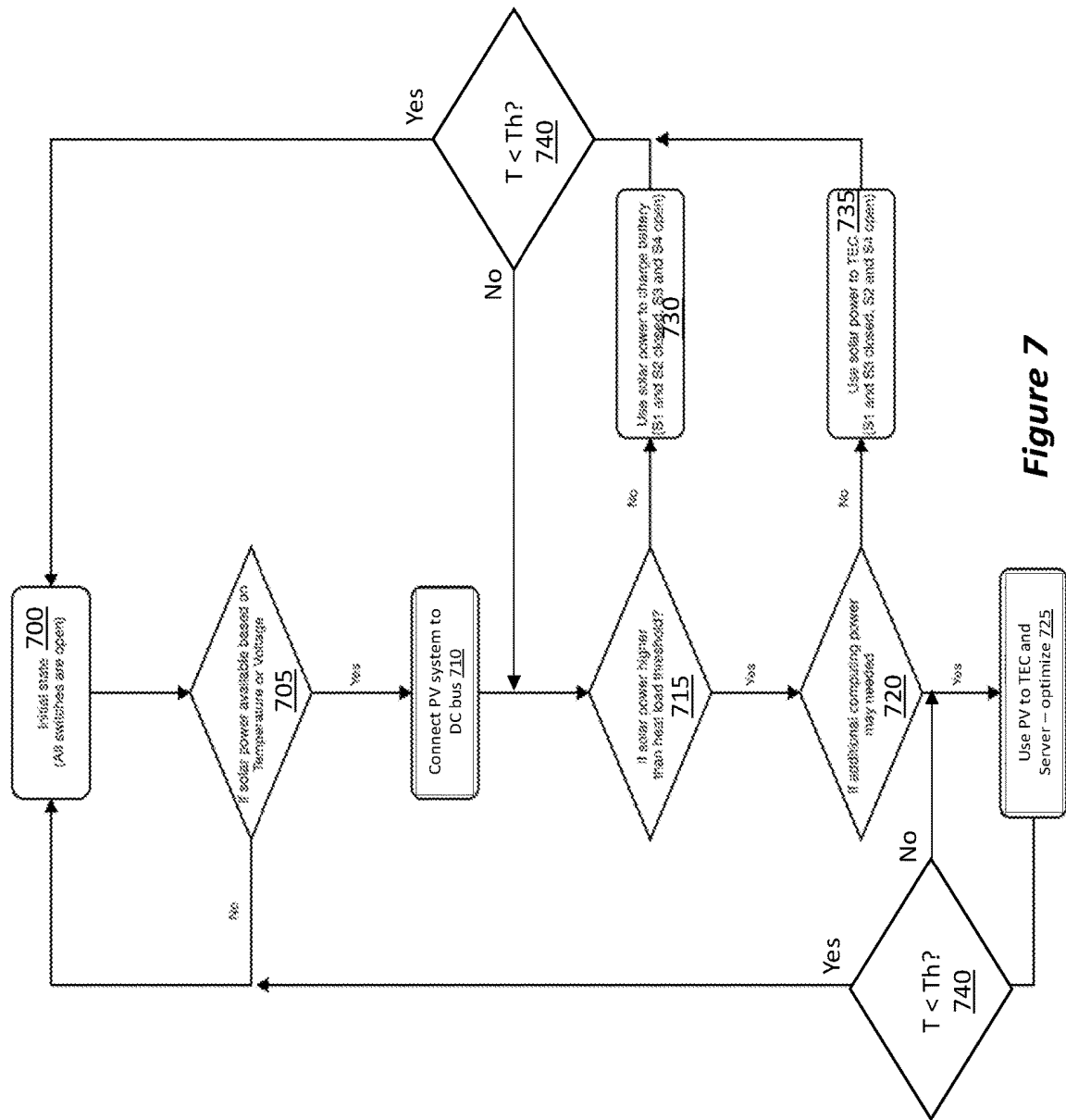


Figure 7

TEMPERATURE BASED SELF-REGULATED COOLING ENHANCEMENT

FIELD OF THE DISCLOSURE

[0001] Embodiments of the present disclosure relate generally to architecture for powering data centers and the IT clusters and equipment within the data centers and, more particularly, to self-regulated power distribution based on temperature measurements.

BACKGROUND

[0002] Generally, data centers incorporate redundant power supply to the servers and the various ancillary equipment (such as cooling, lights, etc.) so as to ensure uninterruptible service. The power supplies may include utility power (provided by utilities companies), diesel generators, and battery backup. In modern data centers the utility power may be delivered to the servers via Uninterruptible Power Supplies (UPS), which perform the required power conditioning and charge the backup battery banks. The UPSs also provide backup power through lead-acid batteries for a short-duration utility power interruption; however, if a longer period interruption occurs, the diesel generators provide the backup power.

[0003] The power supply redundancy required in order to ensure uninterruptible operation increases the cost and complexity of the data center. Moreover, much of the equipment that is dedicated for redundancy idles most of the time, thereby leading to inefficient use of resources. This is exacerbated by the fact that the backup equipment requires periodic maintenance even if it is not used.

[0004] There has been lately an increasing focus on developing and introducing solar systems to power data centers. However, solar power depends on the availability and direction of sunlight, such that its output is cyclic over 24 hours period and also variable during daytime depending on cloud coverage and sun angle. Moreover, the data center load may also be variable and cyclic over different periods, e.g., first level of demand during work hours and possibly a second level of demand during backup performed over non-working hours. Consequently, there is a mismatch between level of power provided by a PV system and the level of load generated by the data center.

[0005] The control of implementing a new power source to data center is also a challenge since it may involve complex power dispatch for different workloads. It is critical to develop robust solutions for controlling the power sources for powering data centers.

[0006] A new design is needed for proper utilization of solar power that includes a simplified, preferably self-regulating, control system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Embodiments of the invention are illustrated by way of example and not limitation in the figures of the accompanying drawings in which like references indicate similar elements.

[0008] FIG. 1 is a block diagram illustrating an example of system architecture according to an embodiment.

[0009] FIG. 2 illustrates a block diagram of another power control arrangement according to an embodiment.

[0010] FIG. 3 illustrates an example of a solar power system which includes powering a cooling pump, according to disclosed embodiments.

[0011] FIG. 4 illustrates an example of a set-up wherein utility and solar power are used for the cooling system, according to disclosed embodiments.

[0012] FIG. 5 illustrates an example of solar power design which include enhanced cooling pump, according to an embodiment.

[0013] FIG. 6 illustrates an example of a control flow according to an embodiment.

[0014] FIG. 7 illustrates an example of a control flow according to another embodiment.

DETAILED DESCRIPTION

[0015] Various embodiments and aspects of the inventions will be described with reference to details discussed below, and the accompanying drawings will illustrate the various embodiments. The following description and drawings are illustrative of the invention and are not to be construed as limiting the invention. Numerous specific details are described to provide a thorough understanding of various embodiments of the present invention. However, in certain instances, well-known or conventional details are not described in order to provide a concise discussion of embodiments of the present inventions.

[0016] Reference in the specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in conjunction with the embodiment can be included in at least one embodiment of the invention. The appearances of the phrase “in one embodiment” in various places in the specification do not necessarily all refer to the same embodiment.

[0017] The following detailed description provides examples that highlight certain features and aspects of the innovative solar power supply claimed herein. Different embodiments or their combinations may be used for different applications or to achieve different results or benefits. Depending on the outcome sought to be achieved, different features disclosed herein may be utilized partially or to their fullest, alone or in combination with other features, balancing advantages with requirements and constraints. Therefore, certain benefits will be highlighted with reference to different embodiments, but are not limited to the disclosed embodiments. That is, the features disclosed herein are not limited to the embodiment within which they are described, but may be “mixed and matched” with other features and incorporated in other embodiments.

[0018] The current disclosure introduces a modular design and architecture that enables self-regulated power supply for data centers. Disclosed embodiments provide “green” or sustainable solutions that reduce capital and operational costs, and maximize utilization and efficiency of the power distribution network.

[0019] Disclosed embodiments provide architectures for supplying power to data center in efficient manner using simplified control. Disclosed embodiments take advantage of the observation that the same environmental conditions that lead to increased power generation also lead to high power demand by specific elements of the data center, namely, the cooling elements.

[0020] Disclosed embodiments provide a module for supplying electrical power during periods when the cooling system requires increased power, while avoiding increase

consumption of utility power. The need for the cooling system to require power increase can be understood as the cooling system may not satisfy the thermal management under the existing operating condition, which is governed by utility power efficiency requirement. Consequently, the disclosed embodiments reduce operational cost of the data center.

[0021] Disclosed embodiments include design of power system distributed among different cooling elements in the data center. The design consists of two levels: power delivery level and the control level. The embodiments aim at improving the efficiency of power usage during different operating conditions by controlling the power flow according to temperature measurements.

[0022] As for power delivery aspect, modern data center and IT cluster designs require simplification of the system and ease of deployment and operation. Therefore, the modular design approach is beneficial. The disclosed embodiments provide efficient methods for implementing PV systems into the IT cluster, especially given that the PV system may not fully function as a full reliable power source. The disclosed architecture improves the data center power system cost efficiency and at the same time, improve the system robustness without sacrificing the reliability.

[0023] As for the control aspect, disclosed embodiments introduce method of using the PV system with multi-level control approach. Detecting and controlling the PV power is critical and challenging since the PV power is highly dependent on multiple factors. The disclosed design implements a novel detection mechanism which efficiently relegates the utilization of the PV output to proper use cases.

[0024] Disclosed embodiments simplify the control strategy of the solar power. By using the temperature (and optionally load and voltage input) the control is self-governing and correlates well with increased cooling requirement and increased solar power availability. That is, at the time the temperature measurement is high, it means that the cooling requirement is increased and also the solar power availability is increased.

[0025] Disclosed aspects further provide power supply system for data center which is self-regulated. The outside ambient temperature is measured and used for controlling the entire system. The outside temperature is used as a proxy for the PV system output, which is employed to control switches for connecting the PV system to complete a close circuit for powering the load. The PV power is connected to the TEC (thermoelectric cooling) and other cooling enhancement hardware or systems for cooling the IT equipment. A rack level power distribution is used for multiple TEC and/or other cooling units. The power distribution design is used for distributing and controlling the power flow from the PV system to different types of loads, either computing load or cooling load. A controller is used to collect the temperature measurements and control the switches' status, as well as the load analysis. The control design can be integrated in a single controller or in a hierarchy manner.

[0026] FIG. 1 is a general schematic illustrating an embodiment for power distribution system 100 in a data center. The embodiment illustrated in FIG. 1 shows only the power delivery from the PV system 110, since the remaining power delivery arrangement may include any other conventional systems, such as utility power. Also omitted from the drawing is the IT equipment not relevant to the cooling

discussion, since this particular embodiment illustrates the application of solar-generated power solely for the cooling equipment.

[0027] As with conventional systems, rack 125 includes a plurality of TEC, indicated as TEC1-TECn. Each of the TECs extracts heat from a corresponding IT device and transfers the heat to the cooling system 130, which then transfers it to the ambient using, e.g., chillers 135. In this regards, the chiller 135 can be understood as an air-cooled chiller; however, element 135 can be also used for representing different cooling units, such as cooling tower, dry cooler, etc. In an embodiment, the cooling system 130 and 135 can be understood as any type of cooling system for a data center. In this respect, the term ambient is used herein to indicate the atmospheric environment existing outside of the data center.

[0028] Each of the TECs requires electrical power to perform its heat pumping and transfer function. The subject inventor has recognized that the load imposed by the TECs correlates with the ambient temperature, i.e., the required cooling load increases during times that the ambient temperature increases. That is, the ambient temperature increase causes the cooling capacity of the main cooling system to decrease, thus necessitating energizing the TECs to provide enhanced heat transfer. Moreover, the subject inventor has recognized that such cooling load increase actually also correlates with solar power output increase. That is, the increase in ambient temperature generally correlates with increase in sun radiation, thus increase in solar power output. Therefore, in this embodiment a temperature sensor 122 sends to controller 120 a signal indicating the ambient temperature. Based on the signal, the controller operates switches S_1 - S_{n-1} to direct the power generated by the solar system 110 to energize the TECs.

[0029] The temperature sensor 122 can be existing temperature sensor used by data center or data center cooling unit, since the majority of the data center cooling units are equipped with ambient temperature sensors. Also, the temperature sensor can be temperature sensors which are used in the standard cooling system, such as fluid temperature sensors installed on the cooling water loop, the chiller water loop, etc. Such temperature may directly or indirectly be impacted by the ambient temperature and therefore reflect the increasing or decreasing ambient temperature. In other words, the temperature signal received by the controller may be any temperature reading that serves as a proxy to the ambient temperature.

[0030] When the temperature increases, the controller manages and enable the system to provide the power generated by the PV system 110 to the TEC, while when it decreases the controller manages to disconnect the power. When the power is connected and delivered to the TEC units, the TEC will function as thermal pump to pump the heat from the hot side (which contacts the electronic devices) to the cold side (which may contact liquid cooling plate). In this manner, the flow of the electrical current in the PV system enables the thermal transportation of heat from the electronic devices to the cooling system. Consequently, the electronic devices' temperature (such as T_{case}) may temporarily decrease or be maintained at the designated value when the cooling conditions are operable.

[0031] Note that in the embodiment of FIG. 1 the switch S_1 is provided in between the PV system and the DC/DC converter 115. The DC/DC converter 115 conditions and

regulates the power delivered by the PV system. However, when no energy is required for the TEC, the PV system is disconnected from the DC/DC converter 115.

[0032] In one example, server rack 125 includes a dedicated busbar or power delivery design which provides power to TECs of individual servers. The busbar is directly powered by the solar power from the DC/DC converter 115 using a switch that is controlled by the controller 120 according to the signal from the sensor 122.

[0033] In the embodiment illustrated in FIG. 1 the ambient temperature is used for the system control. The cooling system of the IT cluster and data center relies on the outside ambient temperature since the heat is eventually extracted to the atmosphere. Therefore, when the ambient temperature is higher, such as during hot hours of summer days, the cooling capacity may be decrease if no additional mechanical cooling is added. However, when the outside temperature is high, which mostly happens during noon and early afternoon, the sun shines so that solar energy is in high availability. Therefore, the disclosed embodiment utilizes the outside temperature as a proxy for the solar power output from the PV system and uses this indicator to control the solar power circuit through the switches to enhance the cooling capacity of the system.

[0034] By the embodiment of FIG. 1, the system is self-regulated according to the outside ambient temperature. When the outside temperature increases, it triggers the PV system and connects the PV to the TECs to provide enhanced heat extraction and transfer from the IT devices. Once the outside temperature drops, the normal cooling recovers and there is no need for enhanced heat extraction, the PV system may then disconnect from the load.

[0035] FIG. 2 illustrates a somewhat more versatile embodiment wherein the power from the PV system may be used for powering other IT equipment in addition to the cooling elements. The system 200 includes the PV system 210 coupled to switch S_1 , which, when engaged, delivers the power to DC/DC converter 215 to condition and regulate the delivered power. The power from the converter 215 may be supplied to the TEC 226 as in the embodiment of FIG. 1 and, in addition or alternatively, to server 240 and/or storage system 250. Note that each of the TEC 226, server 240 and storage system 250 may stand for a plurality of such elements, i.e., TEC 226 may be a plurality of TECs, server 240 may be a plurality of servers, and storage 250 may be a plurality of storage systems.

[0036] Thus, the embodiment of FIG. 2 enables more diversified utilization of the PV power, since at times the TEC may not be needed even during the high ambient temperature period. This may be, for example, when IT computing power or demand is not high, this means that the IT equipment does not generate large amount of power. The TEC may not need to pump too much heat even though the ambient temperature is high. Under such a scenario, the PV power may still be utilized for multiple types of loads by properly activating either or both of switches S_2 and S_4 .

[0037] The embodiment illustrated in FIG. 2 incorporates two features that, while not exclusively, are particularly beneficial in embodiments wherein the PV power may be used for purposes other than cooling. The first feature is a load controller 224, that communicates to the controller 220 the computational load on the server 240. When the PV power may be used for powering the server 240, the information from the load controller 224 may be used by the

controller 220 to determine the optimized operating strategy for distribution of the PV power. The controller 220 may determine the optimized strategy based on variables such as, e.g., the IT load requirements, the PV output capabilities, and the overall cooling requirement.

[0038] The second feature is the inclusion of optional voltage sensor 217. Voltage sensor 217 is used at the output of the PV system 210 as a backup or alternative for the temperature sensor 222. Since in this embodiment the PV system may also be used for other than cooling system, the backup detection may be used to increase the system reliability, in the case when temperature sensing fails.

[0039] The design shown in FIG. 2 enables a more flexible power management for the rack based on different parameters, including the sever load and ambient temperature, in a more precise manner for higher efficiency.

[0040] FIG. 3 illustrates another embodiment utilizing the PV system 310 for powering TECs 326 as well as other cooling units such as cooling pump 323. The cooling pump 323 may be, for example, the rack level liquid cooling pump (e.g., for liquid cooled cooling plates) or IT level pump. The cooling pump 323 can also be the main pump used for normal cooling operation or an auxiliary pump dedicated for cooling enhancement. It is recommend to design a separate auxiliary pump for such an application. Although there is only one pump 323 illustrated in the figure, there may be multiple pumps including both the main cooling pumps and/or enhanced cooling pumps.

[0041] As in other disclosed embodiments, the controller 320 receives the temperature reading from temperature sensor 322 and determines whether to engage the PV system 310 by closing switch S_1 . The controller determines whether to apply the power from the PV system 310 to the TECs 326 by closing switch S_2 , to the cooling pump 323 by closing switch S_3 , or both. For example, when the temperature outside is hot, the controller 320 may apply the PV power to power both the TEC 326 and Cooling pump 323 for enhanced cooling. The use of the pump 323 increases the flow rate of the cooling fluid, such that the heat removal, e.g., cold plates, can be improved. Conversely, when the ambient temperature decreases, the controller may change the operational mode such that only one of the TEC 326 or pump 323 is powered by the PV system 310.

[0042] In an embodiment, the cooling pump can be other types of cooling units such as fans or valves.

[0043] FIG. 4 provides a more comprehensive illustration of the system architecture, in which both the main utility power source as well as the PV power source are employed. In this embodiment either power source can be used for powering the TEC 426 and cooling pump 423. This arrangement enables enhanced cooling even when the solar panels do not receive sunlight, such as under cloudy conditions.

[0044] The utility power 402 is coupled to the server 440 in a conventional manner. Additionally, utility power 402 is coupled to AC/DC converter 404 via switch S_2 , which is controlled by controller 420. When switch S_2 is closed by the controller, closing switch S_5 will deliver utility power to TECs 426, while closing switch S_6 will deliver utility power to cooling pump 423. When the reading of temperature sensor 422 indicate rising temperature, the controller 420 may engage the PV system 410. To engage the solar power 410, controller 420 closes switch S_1 , and switch S_3 to deliver solar power to TECs 426 and/or switch S_4 to deliver solar power to cooling pump 423. The design utilize the PV power

more efficiently, since it is not only used for the cooling enhancement devices such as TEC, but it is also used for normal operations. As an example, when no TEC is needed, the PV power is directly used for the cooling pump with switch S_4 closed, e.g., under the circumstance when the computing workload is not heavy.

[0045] FIG. 5 illustrates another embodiment of utilizing solar power. In the embodiment of FIG. 5 the solar power may be used to power the IT cooling components as well as the facility side or cluster side cooling enhancement design. The cooling system shown in FIG. 5 represent both a facility level unit, a cluster level unit or rack level unit. The cooling system is used to process and deliver cooling liquid to the IT racks, and receives hot return fluid.

[0046] As in other disclosed embodiments, temperature sensor 522 delivers temperature measurements to the controller 520, which controls the delivery of power from the PV system 510 to the TECs 526 by closing switches S_1 and S_3 . When cooling enhancement is needed, the controller 520 also closes switch S_2 to deliver PV power to the cooling enhancement system.

[0047] Specifically, during normal operation mode, valve 1 is open and cooling pump 1 is operating on utility power. When enhanced cooling is needed, the controller closes switch S_2 to deliver solar power to open valve 2 and energize cooling pump 2. This provides increase cooling liquid flow, which enhances the cooling rate. In this respect, cooling pump 2 is used for cooling enhancement when operating using PV system power.

[0048] FIG. 6 is a flow chart illustrating a process according to an embodiment. This embodiment corresponds to an arrangement wherein the PV power output is dedicated to powering the TEC system. The flow chart shows the fundamental method for controlling the switches using ambient temperature. The temperature can be obtained using sensors that are part of the control system or obtaining reading from existing sensor that form part of the existing data center infrastructure.

[0049] Step 600 indicates the initial state wherein all of the system's switches assume the open position, such that solar power is not applied to the TEC system. In step 605 it is checked whether ambient temperature reading is higher than a preset threshold. If it is not, the process reverts to step 600. Otherwise, if the temperature reading exceeds the threshold, at step 610 the controller activates the solar power connection by closing switch S_1 , thereby connecting the PV system to the converter. The self-activation can be understood as no actual detection may be used or dedicated for the PV system.

[0050] Then, in step 615 the controller closes the switches to the TEC to provide power from the converter to the TEC. Thereafter the controller continues to monitor the temperature, so that so long as the temperature remains high, the connection to the TEC is maintained. Conversely, when in step 620 it is determined that the temperature T dropped below a preset threshold T_h , which may be different from the onset threshold of step 605, the controller reverts to the initial state of step 600, wherein all the switches are opened.

[0051] FIG. 7 is a flow chart illustrating control process according to an embodiment. In the embodiment of FIG. 7, the control operation corresponds to an embodiment wherein the PV system is connected to multiple types of IT loads, as exemplified in several embodiments disclosed herein. There are two design goals implemented by the process of FIG. 7. First, the current operation design can be integrated into

existing infrastructure and control architecture. Second, the process can enable further optimization of the cooling operations.

[0052] The PV power may also be used for battery based energy system, while using the temperature measurements to connect the PV system to the batteries. In this scenario, the temperature set point for connecting the PV system to the batteries may be lower than the set point for running/powering the TEC. As another scenario, when the PV power is used for powering both the TEC and other IT loads, an optimized solution may be configured for performance enhancement, including both cooling performance as well as computing performance.

[0053] In FIG. 7, the initial point is depicted in step 700, wherein all the switches assume the open position. In step 705 it is determined whether usable solar power is available, based on the temperature measurement. As indicated in FIG. 7, optionally, as a backup, voltage measurement may also be used to determine the availability of usable solar power. As shown in FIG. 2, the readings of the temperature sensor 222 and the voltage sensor 217, as well as the switches, are correlated. So long as no usable solar power is available, the process reverts to the initial state of step 700.

[0054] When in step 705 it is determined that usable power is available, in step 710 the main switch is closed so as to connect the PV system to the converter. Then in step 715 it is determined whether the available power is higher than the heat load threshold. If not, the process proceeds to step 730, wherein the converter is connected to charge the batteries. Conversely, if the available power is higher than the heat load threshold, the process proceeds to step 720 to determine whether additional computing power is needed. If not, the process proceeds to step 735 wherein the solar power is applied to the TEC. Conversely, in step 725 the controller applies the PV power to both the TEC and the server while optimizing the power distribution among the TEC and server.

[0055] Thereafter the controller continues to monitor the temperature, so that so long as the temperature remains high, the connection to the load is maintained. Conversely, when in step 740 it is determined that the temperature T dropped below a preset threshold T_h , which may be different from the onset threshold of step 705, the controller reverts to the initial state of step 700, wherein all the switches are opened.

[0056] With the above disclosure, a power supply system for a computing system having a cooling system is provided, the system comprising a solar power system and a controller, the controller connected to an ambient temperature sensor measuring the ambient temperature outside the facility housing the computing system, wherein when the temperature sensor provides a temperature reading that is above a present threshold the controller is programmed to connect the solar power system to a power converter and connect the power converter to the cooling system.

[0057] In the disclosed embodiments, the cooling system may include thermoelectric cooling TEC and cooling pumps. Also, the solar power may be applied to the servers within the computing system and/or to batteries. The controller may alternate the supplied power between utility power and solar power according to the temperature reading of the temperature sensor. A voltage sensor may be positioned to read the voltage provided by the solar system as a backup to the temperature sensor.

[0058] In the foregoing specification, embodiments of the invention have been described with reference to specific exemplary embodiments thereof. It will be evident that various modifications may be made thereto without departing from the broader spirit and scope of the invention as set forth in the following claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

What is claimed is:

1. A self-regulated power system for supplying electrical power to an IT system, comprising:

- a photovoltaic (PV) system;
- a power converter;
- a main switch interposed between the PV system and the power converter;
- a temperature sensor;
- a cooling system for cooling IT equipment; and,
- a controller receiving temperature readings from the temperature sensor and activating the main switch to connect the PV system to the power converter to deliver solar power to the cooling system when the temperature reading is above a preset threshold.

2. The system of claim 1, wherein the cooling system comprises a plurality of thermoelectric coolers (TEC).

3. The system of claim 2, wherein each of the TECs is interposed between a respective processor and a cooling device.

4. The system of claim 1, further comprising a supply switch interposed between the power converter and the cooling system and activated by the controller.

5. The system of claim 4, further comprising a compute server and a secondary switch interposed between the power converter and the compute server, the secondary switch activated by the controller.

6. The system of claim 5, further comprising a load controller transmitting to the controller a signal indicative of the computing load of the compute server.

7. The system of claim 6, wherein the temperature sensor forms an integral part of the cooling system.

8. The system of claim 2, wherein the cooling system further comprises:

- at least one cooling pump;
- a first power switch interposed between the power converter and the plurality of TECs; and,
- a second power switch interposed between the power converter and the at least one cooling pump;

wherein the first and second power switches are activated by the controller.

9. The system of claim 2, wherein the cooling system further comprises:

- a main cooling pump coupled to utility power and operable to pump cooling liquid via a main valve;
- a secondary pump operable to pump cooling liquid via secondary valve;
- secondary switch interposed between the power converter and the secondary pump and operable by the controller to deliver PV power to the secondary pump when the temperature reading is above the preset threshold.

10. A power supply system for data center having a plurality of servers and a plurality of thermoelectric coolers (TECs) configured to extract heat from the servers, comprising:

- a utility power system coupled to the plurality of servers;
- an AC/DC converter;

- a utility power switch interposed between the utility power system and the AC/DC converter;

- a utility supply switch interposed between the AC/DC converter and the plurality of TECs;

- a photovoltaic (PV) system;

- a DC/DC converter;

- a PV switch interposed between the PV system and the DC/DC converter;

- a PV supply switch interposed between the DC/DC converter and the plurality of TECs;

- a temperature sensor; and,

- a controller receiving temperature readings from the temperature sensor and activating the PV switch and the PV supply switch to connect the PV system to the DC/DC converter and the DC/DC converter to the plurality of TECs to deliver solar power to the TECs when the temperature reading is above a preset threshold.

11. The system of claim 10, wherein the temperature sensor reads ambient atmospheric temperature exterior to the data center.

12. The system of claim 11, further comprising at least one cooling pump, the cooling pump being coupled to the AC/DC converter via a first switch and coupled to the DC/DC converter via a second switch.

13. The system of claim 11, further comprising main cooling pump coupled to the utility power system and a secondary pump coupled to the DC/DC converter.

14. The system of claim 12, further comprising load controller sending signals to the controller indicative of computational load of the servers.

15. A method for energizing a data center having a plurality of servers and a plurality of thermoelectric coolers (TECs) configured to extract heat from the servers, comprising:

- measuring ambient temperature exterior to the data center;

- monitoring the ambient temperature to determine when the ambient temperature is above a preset threshold and at that time activating a first switch to connect a photovoltaic (PV) system to a DC/DC converter, and activating a second switch to connect the DC/DC converter to the plurality of TECs.

16. The method of claim 15, further comprising continuing to monitor the ambient temperature to determine when the ambient temperature drops below a second threshold and at that time disconnecting the first switch and the second switch.

17. The method of claim 16, further comprising monitoring power level provided by the PV system to determine when the power level exceeds a heat load threshold and, at that time, coupling the PV system to a battery bank to charge the battery bank.

18. The method of claim 15, further comprising monitoring voltage output of the PV system as a backup to the ambient temperature measurement.

19. The method of claim 15, further comprising monitoring computational load of the plurality of servers and when the computational load exceeds a load threshold coupling the PV system to the plurality of servers to apply solar power to the plurality of servers.

20. The method of claim **15**, further comprising when the ambient temperature is above a preset threshold connecting the PV system to a cooling unit.

* * * * *



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(54) Title: SYSTEM FOR COOLING A SOLAR PANEL ASSEMBLY

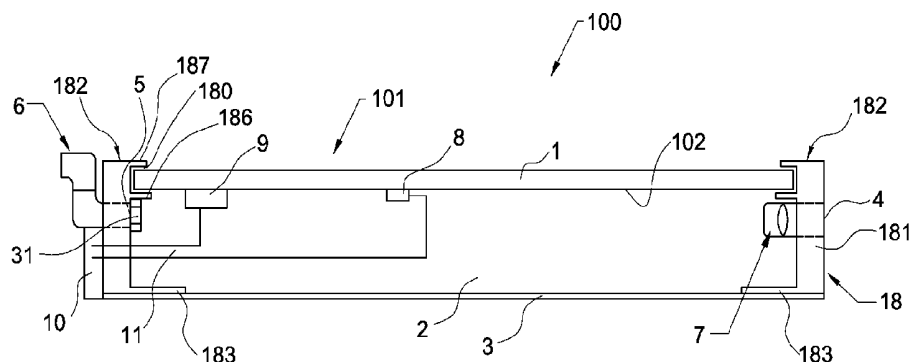


Fig. 1A

(57) Abstract: A cooling system for cooling a solar panel assembly including at least one photovoltaic (PV) module having a plurality of solar cells is described. The cooling system includes a solar panel frame holding the SPA, a bottom plate (3) hermetically attached to the frame to create a water chamber underneath the PV module for holding water for cooling the PV module. The cooling system also includes a stream spreader arranged within the water chamber to provide a uniform fluid dynamic within the water chamber, a pipe adapter to provide a freedom of movement of the solar panel assembly, and a temperature sensor to measure temperature of the PV module at a back sheet of the PV module. The cooling system also includes an external PV junction box mounted outside of the water chamber so as to provide easy accessibility to electrical terminals of the PV module and the temperature sensor.



LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

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SYSTEM FOR COOLING A SOLAR PANEL ASSEMBLY

TECHNOLOGICAL FIELD

This invention relates to cooling systems, and, in particular, to solar panel cooling systems.

BACKGROUND

5 A solar panel includes a plurality of modules having photovoltaic (PV) cells that collect light from the sun and convert the incident solar irradiance to electricity. Photovoltaic cells absorb approximately 80% of the incident light, however conversion inefficiencies of solar cells result in only a portion of incident light energy being converted into electrical energy. The rest of the absorbed solar energy is converted into other forms of energy, mostly
10 thermal energy.

Efficiency of the photovoltaic cells in converting solar energy to electricity highly depends on the temperature of the photovoltaic cell, in particular the warmer the cells, the lower the efficiency and/or production of electricity by the cells. Therefore, it is essential to develop effective cooling systems for photovoltaic panels, which can significantly improve
15 both efficiency and lifetime.

Heat from PV modules can be extracted either actively, for example, by using water cooling, forced air cooling, thermoelectric cooling and heat pipes, or passively, for example, by using Phase Change Materials (PCMs), heat sinks and natural air cooling. Conventional cooling systems are based on a pumped water system that sprays water on the front (or back)
20 of the panels, either when the temperature is measured to rise above a certain threshold, or at selected time intervals. While this approach can cool the PV panels, it has many shortcomings, such as water wastage, energy wastage, high pump switching frequency, etc. Moreover, if water is sprayed on the front of the PV panel, it can result in possible staining of the glass, or build-up of salts.

25 The systems that use heat exchangers installed at the back of photovoltaic modules to extract heat from the module are limited by the thermal conductivity between the solar

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cells and the coolant inside the heat exchanger. Furthermore, such systems are usually focused on producing hot water rather than considerably increasing the electrical efficiency of PV modules.

For example, U.S. Pat. No. 9,070,808 describes cooling systems for solar cells that provide fluid passageways, e.g. pipes, tubes, or channels that are in contact with the solar cells and through which a cooling fluid is streamed to absorb heat from the solar cells.

U.S. Pat. No. 10,050,584 describes a solar panel cooling system that includes a shroud that may be coupled to a back side of a solar panel. The shroud encloses a space on the back side of the solar panel and includes a nozzle for spraying cooling fluid onto the back side of the solar panel. The cooling fluid spray is contained within the space and is recirculated through a closed loop system to cool the cooling fluid before again being sprayed by the nozzle. Thermal energy absorbed by the solar panel is transferred to the cooling fluid to cool the solar panel.

U.S. Pat. No. 9,660,573 describes a solar panel enclosure that converts sunlight to electricity. To remove the large amount of heat from the enclosure, a chambered heat exchanger (CHE) is thermally coupled thereto. An air temperature differential is created between chamber air in a CHE portion and chamber air within a CHE heat exchanging portion. When a threshold thermal gradient is reached, air pressure that keeps the chamber air static, is overcome, creating airflow within the chamber. The airflow draws cooler ambient air from a chamber inlet. Heat from the enclosure is transferred to the cool air and is exhausted from a chamber outlet.

GENERAL DESCRIPTION

Despite prior art in the area of cooling for cooling solar panels, there is still a need in the art for further improvement in order to provide a novel system that can provide more efficient and controllable temperature decrease of the photovoltaic (PV) cells.

The present invention satisfies the aforementioned needs in the art by providing a novel system for cooling a solar panel assembly including at least one photovoltaic (PV) module having a plurality of solar cells generating electrical power and a PV junction box attached to the back of the photovoltaic (PV) module.

According to an embodiment of the present invention, the cooling system includes a solar panel frame that includes a frame wall having a panel holder holding the solar panel assembly at an upper part of the frame wall, and frame base ledges projecting from

opposite sides of the frame wall along the length and/or width of the solar panel frame at a lower part of the frame wall.

According to an embodiment of the present invention, the solar panel frame includes an upper top ledge and a lower top ledge projecting from opposite sides of the frame wall of the solar panel frame at an upper part of the frame wall. According to this
5 embodiment, the panel holder is an integrated part of the frame wall and includes and includes a slot formed by the upper and lower top frame ledges and adapted to hold the solar panel assembly.

According to an embodiment of the present invention, the cooling system includes
10 a bottom plate hermetically attached to the frame base ledges to create a water chamber directly underneath the PV module of the solar panel assembly for holding water for cooling the PV module. The water chamber is defined by a back sheet of the PV module, the frame wall and the bottom plate. Examples of materials suitable for the bottom plate include, but are not limited to, aluminum, stainless steel, polyethylene terephthalate
15 (PET), Polypropylene, Polyimide, etc.

According to still another embodiment of the present invention, the solar panel frame includes only the lower top ledge projecting from opposite sides of the frame wall of the solar panel frame at an upper part of the frame wall. In this embodiment, the panel holder is a separate part of the frame wall tightly attached to the frame wall. The panel holder includes
20 the upper top ledge forming, together with the lower top ledge, the slot that is adapted to hold the solar panel assembly. The panel holder can be tightly coupled to the solar panel frame by using fasteners. Examples of the fasteners include, but are not limited to various possible components, such as sealed blind rivets or CamlocTM fasteners, etc.

According to an embodiment of the present invention, the water chamber is
25 created by attaching the bottom plate to an outer surface of the frame base ledges of the solar panel frame.

According to another embodiment of the present invention, the water chamber is created by attaching the bottom plate to an inner surface of the frame base ledges of the solar panel frame.

30 According to another embodiment of the present invention, the frame base ledges, which project from to the longitudinal sides of the solar panel frame, are connected together to form the bottom plate. In this case the bottom plate is integrated with the frame wall.

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According to a further embodiment of the present invention, the cooling system further includes a solid water tank that forms the water chamber. The water tank is fitted directly into a gap at the back of the solar panel frame.

According to yet a further embodiment of the present invention, the cooling
5 system further includes an inflatable water tank that forms the water chamber. The inflatable water tank, when inflated, is fitted directly into a gap at the back of the solar panel frame, and is fixed to the back sheet of the solar panel assembly.

According to an embodiment of the present invention, the water chamber includes a water inlet arranged in the frame wall at one end of the chamber, and a water outlet
10 arranged in the frame wall at the opposite end of the chamber along the length of the frame.

According to an embodiment of the present invention, the cooling system includes a stream spreader arranged within the water chamber. The stream spreader is hydraulically coupled to the inlet on an inner surface of the frame wall. The stream
15 spreader is configured to provide a uniform fluid dynamic within the water chamber.

According to an embodiment of the present invention, the stream spreader includes an assembly of a T-elbow joint connected to the water inlet at one end, and two 45° elbow joints connected to two other ends of the T-elbow joint, correspondingly. The openings of the two 45° elbow joints are directed towards an inner face of the frame wall.

20 According to an embodiment of the present invention, the cooling system includes a pipe adapter hydraulically coupled to the water outlet on an outer surface of the frame wall. The pipe adapter is configured to provide a freedom of movement of the solar panel assembly that is required for tilting the solar panel assembly.

According to an embodiment of the present invention, the pipe adapter includes
25 two 90° elbow joints. An installation angle of the tilting of the solar panel assembly with respect to a surface of an installation platform is selected such that the PV module(s) could face the sun radiation in order to optimize power generation. Then, the pipe adapter is rotated in such a way that the water in the water chamber is in complete contact with the back sheet of the PV module(s).

30 According to an embodiment of the present invention, the cooling system includes a temperature sensor attached to the back sheet of the PV module. The temperature sensor is configured to generate a temperature sensor signal, which is an electrical signal representative of the temperature at the back sheet of the PV module. The temperature

sensor and the PV junction box are attached to the back sheet of the PV module, and are located within the water chamber that is intended to be filled with water. Therefore, the temperature sensor and the PV junction box are both sealed off by a waterproof material.

According to an embodiment of the present invention, the cooling system also
5 includes an external PV junction box mounted outside of the water chamber. The external PV junction box is electrically connected to the PV junction box and to the temperature sensor, which are both located within the water chamber, to provide easy accessibility to electrical terminals of the PV module and to the temperature sensor.

The cooling system of the present invention can be implemented in several
10 installation configurations.

According to an embodiment of the present invention, the cooling system is installed on an installation surface at a predetermined installation angle with respect to the installation surface. The water inlet of the solar panel assembly can be arranged in the frame wall at the bottom of the solar panel frame, and is hydraulically coupled to a local
15 water supply pipe. The installation surface can, for example, be a roof of a building. In this case, the water outlet of the solar panel assembly is arranged in the frame wall at the top of the solar panel frame and is hydraulically coupled to a water release pipe coupled to a general water supply pipe of the building.

According to another embodiment of the present invention, the cooling system is
20 also installed on an installation surface at a predetermined installation angle with respect to the installation surface. The installation surface can, for example, be a roof of a building. In this embodiment, the water inlet is arranged in the frame wall at the top of the solar panel frame and is hydraulically coupled to a local water supply pipe, while the water outlet is arranged in the frame wall at the bottom of the solar panel frame and is
25 hydraulically coupled to a water release valve coupled to a general water supply pipe of the building.

According to a further embodiment of the present invention, the cooling system is also installed on an installation surface and further includes a water heating system installed on the roof. In this case, the water heating system is hydraulically coupled to the
30 water outlet of the solar panel assembly through a pipe. In turn, the water inlet of the solar panel assembly is hydraulically coupled to the local water supply pipe.

According to yet another embodiment of the present invention, the cooling system is also installed on an installation surface. However, in this embodiment, the cooling

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system further includes a water storage tank installed on the installation surface, and a controllable water pump arranged in a manifold hydraulically coupling the water storage tank to the water inlet of the solar panel assembly. The controllable water pump is configured for regulating a flow rate of egress of the water from the water storage tank
5 into the water chamber formed in the solar panel frame.

According to this embodiment, the cooling system also includes a control unit operatively coupled to the controllable water pump. The control unit is configured for controlling operation of the controllable water pump for supply of cold water from the water storage tank. The control unit is electrically coupled to the temperature sensor
10 attached to the back sheet of the PV module via the PV junction box and via the external PV junction box mounted outside of the water chamber. In operation, the control unit is responsive to the temperature sensor signal generated by the temperature sensor, and is capable of generating control signals for controlling operation of the controllable water pump by switching it “on” or “off”, thereby providing a pulsed supply of water from the
15 water storage tank into the water chamber formed in the solar panel frame.

According to this embodiment, the cooling system also includes a one way valve located within the manifold between the water storage tank and the controllable water pump, thereby to ensure that the water chamber remains filled with water permanently.

According to still another embodiment of the present invention, the cooling
20 system is installed on water on a platform at a predetermined installation angle with respect to a surface of the platform. For example, the platform can be mounted at sea. In this case, the cooling system further includes a controllable water pump hydraulically coupled to the water inlet through a manifold. The controllable water pump is configured to controllably pump seawater from the sea to the water chamber through the water inlet
25 arranged in the frame wall at the bottom of the solar panel frame, and to push the seawater heated in the water chamber to a water release pipe through the water outlet arranged in the frame wall at the top of the solar panel frame.

The controllable water pump is configured for regulating a flow rate of ingress of the sea-water into the water chamber formed in the solar panel frame. Accordingly, the
30 cooling system includes a control unit operatively coupled to the controllable water pump. The control unit is configured for controlling operation of the controllable water pump for supplying seawater. The control unit is electrically coupled to the temperature sensor attached to the back sheet of the PV module via the external PV junction box mounted

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outside of the water chamber. In operation, the control unit is responsive to the temperature sensor signal generated by the temperature sensor, and is capable of generating control signals for controlling operation of the controllable water pump by switching it “on” or “off”, thereby providing a pulsed supply of sea-water into the water
5 chamber.

In this embodiment, a one-way valve is located within a water supply pipe, thereby to ensure that the water chamber remains filled with water permanently.

According to still another embodiment of the present invention, the cooling system is also installed offshore in the sea on a floating platform at a predetermined
10 installation angle with respect to a surface of the floating platform. Contrary to the previous embodiment, in this case, the controllable water pump is configured to controllably pump seawater to the water chamber through the water inlet, which is arranged at the top of the solar panel frame, and to push the seawater heated in the water chamber to a water release pipe through the water outlet, which is arranged at the bottom
15 of the solar panel frame.

According to still another embodiment of the present invention, the cooling system is integrated with a reverse osmosis plant. In this case, the cooling system is installed on a platform mounted on water or on land near sea at a predetermined installation angle with respect to a surface of the platform. The water inlet of the solar
20 panel assembly is arranged in the frame wall at the bottom of the solar panel frame and is hydraulically coupled to the reverse osmosis plant configured to receive seawater from the sea. The water outlet of the solar panel assembly is arranged at the top of the solar panel frame and is hydraulically coupled to a water release pipe.

The system for cooling of the present invention has many of the advantages of the
25 prior art techniques, while simultaneously overcoming some of the disadvantages normally associated therewith.

The system for cooling of the present invention can result in a significant net energy gain when used to cool PV panels. For the configuration, when the installation is a closed system, the cooling system can operate with no extra water consumption. Since
30 the system is closed, and water is in contact with the back of the PV modules, the water does not stain the PV modules.

The cooling system of the present invention can be advantageous for offshore or floating photovoltaic installations, due to unlimited water resources being available.

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However, the cooling system of the present invention can also be used to aid in the water heating system of buildings, thus also reducing net electrical consumption. It should be noted that the cooling system of the present invention can also allow for buildings to remove water storage tanks completely from their roofs, which will free up space and
5 save money.

The cooling system according to the present invention may be efficiently manufactured. The installation of the cooling system to a PV module is relatively quick and easy, and can be accomplished without substantial altering the solar panel frame, with which it is to be associated. The configuration of the cooling system can be retro-fitted
10 on existing conventional photovoltaic installations in a very short time, with minimal modifications. When desired, a kit with new components can be used for modification of existing systems.

The cooling system according to the present invention is of durable and reliable construction.

15 There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows hereinafter may be better understood. Additional details and advantages of the invention will be set forth in the detailed description, and in part will be appreciated from the description, or may be learned by practice of the invention.

20 BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

25 **Figs. 1A, 1B and 1C** illustrate schematic longitudinal cross-sectional side, top and back views, correspondingly, of a cooling system, according to one embodiment of the present invention;

Fig. 2 illustrates an example of a stream spreader of the cooling system shown in Figs. 1A-1C;

30 **Fig. 3** illustrates an example of a pipe adapter of the cooling system shown in Figs. 1A-1C;

Fig. 4 illustrates a schematic transverse cross-sectional side view along the width of the cooling system shown in Figs. 1A-1C;

Fig. 5 shows an isometric view of a cross-section along the width of the cooling system, according to an embodiment of the present invention;

5 **Figs. 6 through 8** show a schematic transverse cross-sectional side view along the width of the cooling system, according to various embodiments of the present invention;

Fig. 9 shows an isometric view of the water tank of **Fig. 8** designed for installation within the solar panel frame, according to an embodiment of the present invention;

10 **Fig. 10** shows a schematic transverse cross-sectional side view along the width of the cooling system **100** of **Figs. 1A-1C**, according to yet an embodiment of the present invention;

Figs. 11 through 14 show schematic longitudinal cross-sectional side views along the length of the cooling system installed on a roof of a building, according to several
15 embodiments of the present invention;

Figs. 15 and 16 show schematic longitudinal cross-sectional side views along the length of the cooling system installed offshore in the sea, according to several embodiments of the present invention; and

Fig. 17 shows a schematic longitudinal cross-sectional side view along the length
20 of the cooling system integrated with a reverse osmosis plant, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

The principles and operation of the cooling system and method for cooling an
25 external surface of a heat conductive body according to the present invention may be better understood with reference to the drawings and the accompanying description, it being understood that these drawings and examples in the description are given for illustrative purposes only, and are not meant to be limiting. The same reference Roman numerals and alphabetic characters will be utilized for identifying those components which are common
30 in the cooling system and its components shown in the drawings throughout the present description of the invention. It should be noted that the blocks in the drawings illustrating various embodiments of the present invention are intended as functional entities only, such

that the functional relationships between the entities are shown, rather than any physical connections and/or physical relationships. Terms, such as "on", "above", "below", "side", "top", "bottom", "upper", "lower", "over", "under", etc. are defined with respect to the horizontal plane.

5 Referring now to **Figs. 1A, 1B and 1C** together, schematic longitudinal cross-sectional side, top and back views, correspondingly, of a cooling system **100** for cooling a solar panel assembly **101** are illustrated, according to an embodiment of the present invention. The solar panel assembly **101** includes one or more photovoltaic (PV) modules **1** having a plurality of solar cells generating electrical power. The solar cells are usually
10 encapsulated in an elastomeric polymer material, such as Ethylene-vinyl acetate (EVA), which are then "sandwiched" between a polymer back sheet and a glass front sheet. **Fig. 1B** shows a top-view of the cooling system **100** with the central part showing a fragment of the photovoltaic (PV) module(s) **1** and the sides of the cooling system **100** showing an internal view of the solar panel assembly **101**.

15 As shown in **Figs. 1A and 1C**, the solar panel assembly **101** also includes a PV junction box **9** attached to the back of the solar panel assembly **101**. The PV junction box **9** is a conventional device including, *inter alia*, bypass diodes to protect the PV modules from reverse current during hours of darkness, or if the PV modules are in shade. The PV junction box **9** serves as the interface between the conductor ribbons on the PV
20 modules and the DC input and output cables (not shown). The PV junction box **9** is usually installed by photovoltaic (PV) manufacturers directly onto the back of the solar panel assembly **101**, and is usually attached to the back of the solar panel assembly **101** with silicon adhesive.

The solar panel assembly **101** of the cooling system **100** usually includes a solar
25 panel frame **18**. The solar panel frame **18** includes a frame wall **181** having a panel holder **182** adapted for holding the PV module(s) **1** at an upper part of the frame wall **181**, and frame base ledges **183** projecting from opposite sides of the frame wall **181** along the length and/or width of the solar panel frame **18** at a lower part of the frame wall **181**.

According to an embodiment of the present invention, the solar panel frame **18**
30 includes an upper top ledge **187** and a lower top ledge **186** projecting from opposite sides of the frame wall **181** of the solar panel frame **18** at an upper part of the frame wall **181**. According to this embodiment, the panel holder **182** is an integrated part of the frame wall **181** and includes and includes a slot **180** formed by the upper and lower top frame

ledges **187** and **186** adapted to hold the solar panel assembly **101**. The solar panel frame **18** can, for example, be made from aluminum, however other materials are also contemplated.

According to an embodiment of the present invention, the cooling system **100** includes a bottom plate **3** hermetically attached to the frame base ledges **183** to create a water chamber **2** directly underneath the PV module(s) **1** for holding water required for cooling the solar panel assembly **101**. Specifically, the water chamber **2** is defined by a back sheet **102** of the PV module **1**, the frame wall **181** and by the bottom plate **3**. The bottom plate **3** can, for example, be made of aluminum or a polymer, such as polyethylene terephthalate (PET). The bottom plate **3** can be attached to the frame base ledges **183** with silicon adhesive or by industrial welding, brazing, soldering or any other suitable industrial technique.

According to an embodiment of the present invention, the water chamber **2** of the cooling system **100** includes a water inlet **4** arranged in the frame wall **181** at one end of the water chamber **2** and a water outlet **5** arranged in the frame wall **181** at the opposite end of the chamber **2**.

According to an embodiment of the present invention, the back sheet of the solar panel assembly **101** has an extra layer of protection, for example, an acrylic layer sprayed on the surface of a conventional back sheet, since in operation of the cooling system, it is in direct contact with it. Likewise, the damaging effect of water can also be avoided by improving the back sheet material itself, for example, by covering the conventional back sheet of the solar panel assembly **101** by a metal layer resistant to water. This would also improve the thermal conductivity of the back sheet that can make the system more efficient.

According to an embodiment of the present invention, the cooling system **100** includes a stream spreader **7** arranged within the water chamber **2** and which is hydraulically coupled to the inlet **4** on an inner surface of the frame wall **181**. The stream spreader **7** is configured to provide a uniform fluid dynamic within the water chamber **2**.

Fig. 2 illustrates an example of the stream spreader **7** suitable for the cooling system **100**. As shown in **Fig. 2**, the stream spreader **7** includes an assembly of a T-elbow joint **71** connected to the water inlet **4** at one end, and two 45° elbow joints **72** connected to two other ends of the T-elbow joint, correspondingly. The openings **73** of the two 45° elbow joints are directed towards an inner face **74** of the frame wall **181** to forward the

water stream on the frame wall **181** in order to improve the fluid dynamics when cold water is introduced into the system. This provision allows hotter water to be pushed out of the water chamber **2** through the outlet **4** with as little mixing with colder water as possible.

5 Turning back to **Figs. 1A, 1B and 1C**, according to an embodiment of the present invention, the cooling system **100** further includes a pipe adapter **6** hydraulically coupled to the water outlet **5** on an outer surface of the frame wall **181**. The pipe adapter **6** is configured to provide a freedom of movement of the solar panel assembly **101** required for tilting the solar panel assembly **101**.

10 **Fig. 3** illustrates an example of the pipe adapter **6** suitable for the cooling system **100**. As shown in **Fig. 3**, the pipe adapter **6** includes two 90° elbow joints **61a** and **61b**, which can be pivotally adjusted with respect to each other and with respect to the frame wall **181** at the desired positions during installation of the cooling system **100** on the installation platform.

15 An installation angle of the tilting of the solar panel assembly **101** with respect to a surface of an installation platform is selected such that the PV module(s) **1** could face the sun radiation in order to optimize power generation. Then, the pipe adapter **6** is rotated such a way that the water in the water chamber **2** is in complete contact with the back sheet **102** of the PV module(s) **1**.

20 Referring back to **Figs. 1A and 1C** together, according to an embodiment of the present invention, the cooling system **100** further includes a temperature sensor **8** attached to the back sheet **102** of the PV module **1** configured to generate a temperature sensor signal representative of the temperature of the PV module(s) **1** at the back sheet **102** of the PV module. Since the temperature sensor **8** and the PV junction box **9** attached to the
25 back of the PV module **1** are located within the water chamber **2**, these modules are sealed off by a waterproof material, such as liquid resin.

According to an embodiment of the present invention, the cooling system **100** also includes an external PV junction box **10** mounted outside of the water chamber **2**. The external PV junction box **10** duplicates the function of the PV junction box **9** attached to
30 the back of the solar panel assembly **101**, which is located within the water chamber **2**. The external PV junction box **10** is electrically coupled to the temperature sensor **8** and to the PV junction box **9** located within the water chamber **2** by wires **11**, so as to provide easy accessibility to the temperature sensor **8** and to electrical terminals of the PV module.

For example, the external PV junction box **10** can be installed next to the outlet, in order to be able to perform maintenance, such as changing of bypass diodes.

Referring to **Fig. 4**, a schematic transverse cross-sectional side view along the width of the cooling system **100** of **Figs. 1A-1C** is illustrated, according to one embodiment of the present invention. As shown in **Fig. 4**, in operation, the water chamber **2** includes a water reservoir created underneath the solar panel assembly **101**. The water chamber **2** is created by attaching the bottom plate **3** to an outer surface **184** of the frame base ledges **183** of the solar panel frame **18**. This configuration allows for an easier manufacturing process, however a strong bond is required between the bottom plate **3** and the solar panel frame **18** of the cooling system **100** in order for the bottom plate **3** to be able to withstand the weight of the water in the water reservoir and some water pressure within the water chamber **2**. A material suitable for the bottom plate **3** can be selected from various types of materials which include, but are not limited to, aluminum, polyethylene terephthalate (PET) and polypropylene, however other materials are also contemplated. The chosen material, however, needs to be inert when in contact with the aluminum frame **18**.

Fig. 5 shows an isometric view of a cross-section along the width of the cooling system **100**. The “Detail – C” in **Fig. 5** shows a magnified view of the water chamber **2** created under the solar panel assembly **101** when the bottom plate **3** is attached externally to the frame base ledges **183** of the solar panel frame **18**.

Referring to **Fig. 6**, a schematic transverse cross-sectional side view along the width of the cooling system **100** of **Figs. 1A-1C** is illustrated, according to another embodiment of the present invention. As shown in **Fig. 6**, the water chamber **2** is created by attaching the bottom plate **3** to an inner surface **185** of the frame base ledges **183** of the solar panel frame **18**. Contrary to the embodiment shown **Figs. 4 and 5**, in the configuration of **Fig. 6**, the bottom plate **3** is connected with the frame base ledges **183** internally. The advantage of this configuration is that the bonding between the bottom plate **3** and the frame base ledges **183** can withstand higher pressures than in the case of external bonding. However, this configuration may result in a more complex manufacturing process.

Referring to **Fig. 7A**, a schematic transverse cross-sectional side view along the width of the cooling system **100** of **Figs. 1A-1C** is illustrated, according to still another embodiment of the present invention. This embodiment differs from the embodiments shown in **Figs. 4 and 6** by the fact that the frame base ledges **183** which project from the

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longitudinal sides of the solar panel frame **18** are connected together to form the bottom plate **3** that is integrated with the frame wall **181**. It should be understood that the connected frame base ledges **183** close the solar panel frame **18** from the back, while the photovoltaic (PV) modules **1** of the solar cell assembly **101** close the solar panel frame **18** from the top, thereby forming the water chamber **2** that is closed to operate as a water reservoir. The solar panel frame **18** in this embodiment can, for example, be manufactured through a molding manufacturing process. Examples of materials suitable for the solar panel frame **18**, in which the bottom plate **3** is integrated with the frame wall **181**, include, but are not limited to, aluminum and polymers, such as recycled PET, Polyimide or Polypropylene, etc. It should be noted that the material used for the solar panel frame **18** needs to be UV resistant and satisfy compressive and tensile load requirements.

Referring to **Fig. 7B**, a schematic transverse cross-sectional side view along the width of the cooling system **100** is illustrated, according to still another embodiment of the present invention. This embodiment differs from the embodiment shown in **Fig. 7A** by the fact that the solar panel frame **18** includes only the lower top ledge **186** projecting from opposite sides of the frame wall **181** of the solar panel frame **18** at an upper part of the frame wall **181**. In this embodiment, the panel holder **182** is a separate part of the frame wall **181** tightly attached to the frame wall **181**. The panel holder **182** includes the upper top ledge **187** forming, together with the lower top ledge **186**, the slot **180** adapted to hold the solar panel assembly **101**.

The panel holder **182** can be tightly coupled to the solar panel frame **18** by using fasteners **200**. Examples of the fasteners **200** include, but are not limited to various possible components, such as sealed blind rivets or CamlocTM fasteners, etc. This embodiment has the advantages of a simple manufacturing process and also ease of maintenance since the solar cell assembly **101** can be easily removed to give access to the water chamber **2**.

Referring to **Fig. 8**, a schematic transverse cross-sectional side view along the width of the cooling system **100** of **Figs. 1A-1C** is illustrated, according to a further embodiment of the present invention. According to this embodiment, the cooling system **100** further includes a solid water tank **26** that fits directly into the gap at the back of the solar panel frame **18**. The water tank **26** forms the water chamber **2**. The solid water tank **26** can for example, be manufactured from high thermally conductive materials, such as aluminum-plates.

As can be seen in **Fig. 8**, a transverse cross-section of the water tank **26** has a 180°-turned T-shape. The design of the solid water tank **26** is such that its top part is in direct contact with the back sheet of the photovoltaic (PV) modules **1** of the solar cell assembly **101** in order to ensure maximum thermal conductance. A cutout **33** in the top part of the water tank **26** allows for the junction box **9** to fit and not obstruct the thermal coupling between the back sheet of the photovoltaic (PV) modules **1** of the solar cell assembly **101** and an upper wall **261** of the water tank **26**. According to this embodiment, the water chamber **2** is formed by the upper wall **261**, a side wall **262** and a base side **263** of the water tank **26**. The base side **263** operates as the bottom plate (**3** in **Figs. 1A and 1C**).

10 The side **263** of the water tank **26** is attached to the frame base ledges **183** of the solar panel frame **18**. In order to fix the base side **263** of the water tank **26** with the frame base ledges **183**, various possible approaches can be used. According to one example, the base side **263** can be attached adhesively to the frame base ledges **183**. According to another example, the base side **263** can be attached to the frame base ledges **183** by using self-tapping screws. In this case, the base side **263** can include holes **28** at the periphery, in order to facilitate the fixing of the water tank **26** to the solar panel frame **18**.

Reference for a further description is made to **Fig. 8** and **Fig. 9** together, where **Fig. 9** shows an isometric view of the water tank **26** of **Fig. 8**, according to an embodiment of the present invention. As shown in **Fig. 9**, the water tank **26** includes a tank inlet **40** and a tank outlet **50**. When the water tank **26** is mounted within the solar panel frame (**18** in **Figs 1A-1C**), the tank inlet **40** should match the water inlet **4** arranged in the frame wall **181** and the tank outlet **50** should match the water outlet **5** arranged in the frame wall **181**. The exact position of the tank inlet **40** and tank outlet **50** can vary, depending on the corresponding water inlet **4** and water outlet **5** in the solar panel frame **18** in which the water tank **26** is installed.

As shown in **Fig. 9**, the base side **263** includes holes **28** arranged at the periphery, in order to facilitate the fixing of the water tank **26** to the frame base ledges **183** of the solar panel frame **18**. According to this embodiment, in order to accommodate the conventional PV junction box **9**, which is usually placed in the top-central part of a solar panel assembly **101**, the top part of the water tank **26** of the cooling system **100** includes the cut-out **33** that is located near the tank outlet **50** rather than in the central part of the water tank. Such design can facilitate the manufacturing process of the water tank **26**.

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Referring to **Fig. 10**, a schematic transverse cross-sectional side view along the width of the cooling system **100** of **Figs. 1A-1C** is illustrated, according to yet an embodiment of the present invention. According to this embodiment, the cooling system **100** further includes an inflatable water tank **27** that can fit directly into the gap at the back of the solar panel frame **18** when inflated. In this case, the inflatable water tank **27** forms the water chamber **2**. The inflatable water tank **27** can, for example, be made of a flexible, deformable, durable, strong plastic material, rubber material, or any type of polymer based material having a braid or other reinforcement that can sustain large deformation and withstand chemical reactions with water. Examples of materials suitable for the inflatable water tank **27** include, but are not limited to, Polyvinyl Chloride (PVC), Polyurethane (PU), Carbon-Fiber, etc. The large deformation can, for example, be in the range of 10% to 100% volume change.

The inflatable water tank **27** can be fixed to the back sheet of the solar panel assembly **101**, for example, by using a thermally conductive paste, while it is still deflated.

According to an embodiment, the inflatable water tank **27** includes a tank water inlet and a tank water outlet (not shown in **Fig. 10**). The tank can be inflated with water through the water inlet (not shown) arranged in the inflatable water tank **27**. Water flow is possible through the water inlet and outlet.

According to an embodiment, the inflatable water tank **27** includes only a tank water inlet. In this case, the inflatable water tank **27** can be filled with water or any other cooling liquid through the water inlet at manufacturing stage, and is then sealed off with no possibility of water flow. The added specific heat capacity provided by the cooling liquid can still result in an improved photovoltaic conversion efficiency.

The inflatable water tank **27** can be held in place either by resting on an aluminum structure of the frame base ledges **183** or by attaching the bottom plate **3**, made of any rigid material, to the solar panel frame **18** of the cooling system. Since the tank is flexible, it would go around the conventional junction box **9**, when pressed with the back of the solar cell assembly **1**.

The cooling system **100** of the present invention can have various applications.

Referring to **Fig. 11**, a schematic longitudinal cross-sectional side view along the length of the cooling system **100** installed on an installation surface is illustrated, according

to an embodiment of the present invention. As shown in **Fig. 11**, the installation surface is a roof **20** of a building **21**, however other installation surfaces are also contemplated.

In this configuration, the cooling system **100** is installed at a predetermined installation angle with respect to a surface of the roof **20**. An installation angle of the tilting
5 of the solar panel assembly **101** with respect to a surface of an installation platform is selected such that the PV module(s) **1** could face the sun radiation in order to optimize power generation. After mounting the solar panel assembly **101** at the installation angle, the pipe adapter **6** is rotated such a way that the water in the water chamber **2** is in complete contact with the back sheet **102** of the PV module(s) **1**.

10 In this configuration, the water inlet **4** of the solar panel assembly **101** is arranged in the frame wall **181** at the bottom of the solar panel frame **18**, and is hydraulically coupled to a local water supply pipe **24**. The water outlet **5** of the solar panel assembly **101** is hydraulically coupled to a water release pipe **17** connected to a general water supply pipe (not shown) of the building **21**. In this configuration, when an occupant in the building **21**
15 utilises water by opening a general water supply valve **23** arranged in the water release pipe **17**, the warm water located in the water chamber **2** is pushed out into the building's water system through a combination of the water release pipe **17** and the general water supply pipe that can include various possible types of manifolds. Hence, during hot water usage, the water in the water chamber **2** is replaced with cooler water from the local water supply pipe
20 **24**.

It should be noted that this configuration does not need to use a pump controlled by a control system, thus reducing potential points of system malfunction and failure. Thus, the water supply system of the building wastes no energy, since water flow can only be controlled by the frequency of use of water by occupants in that particular building.
25 Furthermore, since it is a closed system, no water is wasted for the purpose of cooling the solar panel assembly **101**.

It should also be noted that the water chamber **2** itself offers the benefit of slowing the temperature rise of the PV panel(s) **1** due to the added specific heat capacity. This also shifts the maximum photovoltaic cell temperature to a later time of the day when solar
30 radiation is not at maximum. Therefore, the decrease in efficiency due to the increase in temperature will not have the same effect as if it occurred at peak irradiance levels.

A further advantage of this mode of operation of the cooling system is that no extra water or electrical consumption is introduced, while still maintaining the temperature of the

PV modules below the normal operating conditions, thus operating the solar panel assembly **101** at a higher efficiency. As can be understood, in this installation, the cooling system **100** can replace a conventional rooftop water storage tank.

Referring to **Fig. 12**, a schematic longitudinal cross-sectional side view along the
5 length of the cooling system **100** installed on an installation surface, e.g., the roof **20** of the building **21**, is illustrated, according to another embodiment of the present invention. In this configuration, the cooling system **100** is also installed at a predetermined installation angle with respect to a surface of the roof **20**. The installation, according to this embodiment, differs from the installation in **Fig. 11** by the fact that the water inlet **4** is arranged in the
10 frame wall **181** at the top of the solar panel frame, while the water outlet **5** is arranged in the frame wall **181** at the bottom of the solar panel frame **18**.

The water inlet **4** of the solar panel assembly **101** is hydraulically coupled to the local water supply pipe **24**. The water outlet **5** of the solar panel assembly **101** is hydraulically coupled to the general water supply pipe of the building **21**. In this configuration, a
15 mechanical air-pressure release valve **34** is utilized in order to avoid trapping and pressurizing air in the water chamber **2** that could cause damage to the system.

According to an embodiment, the water release pipe **17** is preferably sized smaller than the local water supply pipe **24** in order to be sure that the water chamber **2** remains filled with water even when the general water supply valve **23** is opened by an occupant in
20 the building. An advantage of such a configuration is that bulky conventional rooftop water storage tanks can be eliminated and incorporated in the same footprint occupied by the photovoltaic installation. This configuration also has other advantages similar to the advantages of the configuration in **Fig. 11**. For instance, in this installation, the cooling system **100** can replace a conventional rooftop water storage tank.

Referring to **Fig. 13**, a schematic longitudinal cross-sectional side view along the
25 length of the cooling system **100** installed on an installation surface, e.g., the roof **20** of the building **21**, is illustrated, according to a further embodiment of the present invention. The installation, according to this embodiment, differs from the installation in **Fig. 11** by the fact that the cooling system **100** further includes a water heating system **22** (e.g., a boiler)
30 installed on the roof **20** of the building **21**.

As shown in **Fig. 13**, the water inlet **4** is hydraulically coupled to the local water supply pipe **24**, while the water outlet **5** is hydraulically coupled to the building's water heating system **22** through a pipe **170**. This provision allows decreasing the building's net

energy consumption. In this configuration, when an occupant in the building utilizes hot water by opening the general water supply valve **23**, the warm water located in the water chamber **2** is pushed out into the building's water heating system **22** through the pipe **170** that can include various possible types of manifolds.

5 The hot water located in water heating system **22** is released into the building's water system through a combination of the water release pipe **17** and the hot water supply pipe (not shown) of the building. In turn, during hot water usage, the water in the water chamber **2** is replaced with cooler water from the local water supply pipe **24**.

 This configuration has benefits of cooling the solar cell assembly **101**, since it results
10 in a higher electrical efficiency, and also increases the water heating efficiency, since warm water from the water chamber **2** is introduced into the boiler **22** instead of cold water from the local water supply pipe **24**. Similar to the configuration shown in **Fig. 11**, another possible advantage of the configuration shown in **Fig. 13** is that bulky conventional rooftop water storage tanks can be eliminated and incorporated in the same footprint occupied by
15 the photovoltaic installation. Furthermore, with this configuration, no water pump or water supply control is necessary, since water flow can only be controlled by the frequency of use of water by the occupants in that particular building.

 Referring to **Fig. 14**, a schematic longitudinal cross-sectional side view along the length of the cooling system **100** installed on an installation surface, e.g., the roof **20** of the
20 building **21**, is illustrated, according to still a further embodiment of the present invention. According to this embodiment, the cooling system **100** further includes a water storage tank **19** installed on the roof **20** and a controllable water pump **12** arranged in a manifold **171** hydraulically coupling the water storage tank **19** to the water inlet **4**. The controllable water pump **12** is configured for regulating a flow rate of egress of the water from the water storage
25 tank **19** passing into the water chamber **2**. The term "valve" as used herein has a broad meaning and relates to any electrical or mechanical device adapted to controllably regulate the flow rate of the fluid.

 In order to control water ingress into the chamber **2** the cooling system **100** includes a control unit **14**. The control unit **14** is operatively coupled to the controllable water pump
30 **12**, and is configured for controlling operation thereof for supply of cold water from the water storage tank **19**. The control unit **14** is electrically coupled to the temperature sensor **8** attached to the back sheet **102** of the PV module(s) **1** via the external PV junction box **10** mounted outside of the water chamber **2**. The temperature sensor **8** is configured to generate

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a temperature sensor signal representative of the temperature of the PV module(s) **1** at the back sheet **102** of the PV module. The controllable water pump **12** may be a commercially available component.

The controllable water pump **12** can be controlled by the control unit **14** depending
5 on the feedback obtained from the temperature sensor **8**. In operation, the temperature signals produced by the temperature sensor **8** are relayed to the control unit **14** via a connecting cable **141**. The control unit **14** is responsive to the temperature sensor signal and is capable of generating control signals for controlling operation of the controllable water pump **12** by switching it “on” or “off”, thereby providing a pulsed supply of water from the
10 water storage tank **19** into the water chamber **2**.

For example, if the temperature of the back sheet **102** of the PV module(s) **1** is higher than a predetermined threshold temperature, the control unit **14** can produce a temperature control signal to activate operation of the controllable water pump **12** to provide a supply of cold water from the water storage tank **19** to the water chamber **2**. The supply of cold water
15 into the water chamber **2** can continue as long as required for obtaining a desired temperature decrease of the back sheet **102** of the PV module(s) **1**. In turn, hot water located in the water chamber **2** is pushed back to the water storage tank **19** through a water return pipe **172**.

As shown in **Fig. 14**, this configuration of the cooling system includes a one way valve **13** located within the manifold **171** between the water storage tank **19** and the
20 controllable water pump **12** that ensures that the water chamber **2** remains filled with water at all times, even when the controllable water pump **12** is switched off. When an occupant in the building **21** utilises water by opening the general water supply valve **23**, water will flow from the water tank to the building through the water release pipe **17** coupled to the water supply pipe (not shown) of the building.

As shown in **Fig. 14**, this configuration of the cooling system also includes a float
25 valve **29** that is arranged in the water storage tank **19**, in order to maintain a fixed water level inside the tank. In operation, when water is used by the occupants of the building **21**, a float **291** attached to the float valve **29** can move downwards, thus opening the float valve **29**. When the water level in the water storage tank **19** rises, the float **291** rises as well, and
30 eventually closes the float valve **29** to stop a flow of water from the local water supply pipe **24**.

It should be noted that the configuration shown in **Fig. 14** does not waste water, since it is a closed system. Furthermore, the cooling flow is optimised with the use of the non-

return one-way valve **13** arranged within the manifold **171**, since when the controllable water pump **12** is switched off, the water chamber **2** remains filled with water. This can increase the specific heat capacity of the photovoltaic module and therefore the solar cell assembly **101** can take longer time to heat up, when compared to a conventional photovoltaic module.

5 Moreover, this configuration has the advantage of reducing the pump switching frequency, which not only saves energy, but also prolongs the lifetime of the water pump **12**.

Referring to **Fig. 15**, a schematic longitudinal cross-sectional side view along the length of the cooling system **100** installed on water is illustrated, according to an embodiment of the present invention. According to this embodiment, the cooling system

10 **100** can be installed for example, at sea, lake, pond, etc. The entire cooling system **100** is mounted on a floating platform **15**, such as a raft, however other installations of the platform, e.g., a fixed platform, are also contemplated, which can be designed for photovoltaic installations.

In this configuration, the cooling system **100** is installed at a predetermined

15 installation angle with respect to a surface of the floating platform **15**. It should be noted that the presence of an inclination angle is preferred over horizontal installations for offshore applications, since the latter would lead to stagnant water evaporating and leaving large amounts of salt deposit on the photovoltaic module glass.

Similar to the embodiment shown in **Fig. 14**, the cooling system **100** includes a

20 controllable water pump **12** hydraulically coupled to the water inlet **4** through the manifold **171**. The controllable water pump **12** is configured to pump seawater from the sea through the water supply pipe **24** to the water chamber **2**. The water outlet **5** of the solar panel assembly **101** is hydraulically coupled to a water release pipe **17** configured to drain the heated water from the water chamber **2** through various possible types of manifolds into the

25 sea, or to supply it to a user.

According to this embodiment, the cooling system **100** includes the control unit **14** configured to control the controllable water pump **12** as required depending on the feedback obtained from the temperature sensor **8**. In operation, the temperature signals produced by the temperature sensor **8** are relayed to the control unit **14** via a connecting cable **141**. The

30 control unit **14** is responsive to the temperature sensor signal and is capable of generating control signals for controlling operation of the controllable water pump **12** by switching it “on” or “off”, thereby providing a pulsed supply of seawater into the water chamber **2**.

For example, if the temperature of the back sheet **102** of the PV module(s) **1** is higher than a predetermined threshold temperature, the control unit **14** can produce a temperature control signal to activate operation of the controllable water pump **12** to provide a supply of cold seawater to the water chamber **2**. The supply of seawater into the water chamber **2** can
5 continue as long as required for obtaining a desired temperature decrease of the back sheet **102** of the PV module(s) **1**. In turn, hot water located in the water chamber **2** is drained into the sea **16** through the water release pipe **17**.

As shown in **Fig. 15**, this configuration of the cooling system includes a one way valve **13** located within the water supply pipe **24** that ensures that the water chamber **2**
10 remains filled with water at all times, even when the controllable water pump **12** is switched off. This provision can considerably increase the specific heat capacity of the photovoltaic module and therefore the solar cell assembly can take longer to heat up when compared to a conventional photovoltaic module. This embodiment of the cooling system focuses primarily on maintaining the PV temperature within the desired limits and has the advantage
15 of reducing the pump switching frequency, which not only saves energy, but also prolongs the lifetime of the pump.

It should be noted that the configuration of this embodiment is an open system, where the cooling seawater resource is practically unlimited.

Referring to **Fig. 16**, a schematic longitudinal cross-sectional side view along the
20 length of the cooling system **100** installed offshore in the sea is illustrated, according to another embodiment of the present invention. The installation, according to this embodiment, differs from the installation in **Fig. 15** by the fact that the water inlet **4** is arranged in the frame wall **181** at the top of the solar panel frame **18**, while the water outlet **5** is arranged in the frame wall **181** at the bottom of the solar panel frame **18**.

25 Similar to the embodiment shown in **Fig. 15**, the one-way valve **13** ensures that the the water chamber **2** and the water pump **12** remain filled with water at all times, even when the controllable water pump **12** is switched off. However, it should be noted that when a submersible water pump is used instead of underwater pump, the one-way valve can be removed for this configuration.

30 According to the embodiment shown in **Fig. 16**, the cooling system **100** includes a controllable solenoid valve **32** arranged at the water outlet **5**. The control unit **14** is configured to control the controllable solenoid valve **32**. In operation, the controllable solenoid valve **32** is closed when the water pump **12** is switched off, in order to ensure that

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the water chamber **2** remains full of water at all times. This will considerably increase the specific heat capacity of the photovoltaic module, and therefore the solar panel assembly **101** can take longer to heat up when compared to a conventional photovoltaic module. This has the advantage of reducing the pump switching frequency, that not only saves energy, but
5 also prolongs the lifetime of the water pump.

According to an embodiment, the water release pipe **17** is preferably sized smaller than the water supply pipe **24** in order to create a positive pressure inside the water chamber **2** to ensure that it remains filled with water even when solenoid valve **32** is opened and the water pump **12** is switched on.

10 According to the embodiment shown in **Fig. 16**, the cooling system **100** includes a mechanical air-pressure release valve **34** arranged at the water inlet **4**. The air-pressure release valve **34** can be used in order to avoid trapping and pressurizing air in the water chamber **2**, that can cause damage to the cooling system.

The installation of this embodiment focuses primarily on maintaining the
15 temperature of the PV modules within the desired limits, thus operating the solar panel assembly **101** at a higher efficiency.

It should be noted that the configuration of this embodiment is an open system, where the cooling seawater resource is practically unlimited.

Referring to **Fig. 17**, a schematic longitudinal cross-sectional side view along the
20 length of the cooling system **100** integrated with a reverse osmosis plant **35** is illustrated, according to an embodiment of the present invention. The solar panel assembly **101** cooled by cooling system **100** is used to power the reverse osmosis plant **35** using solar energy. As shown in **Fig. 17**, the entire cooling system **100** is mounted on a floating platform **15**, however other installations of the cooling system are also contemplated. In particular, some
25 of the components of the integrated system can be installed on floating platforms, and some on the ground.

As shown in **Fig. 17**, the cooling system **100** is installed at a predetermined installation angle with respect to a surface of the floating platform **15**. It should be noted that the presence of an inclination angle is preferred over horizontal installations for offshore
30 applications, since the latter would lead to stagnant water evaporating and leaving large amounts of salt deposit on the photovoltaic module glass.

The integrated system includes a water pump **120** hydraulically coupled to a water inlet **351** of the reverse osmosis plant **35** through a connecting pipe **74**. The water pump **120**

is configured to collect seawater from the sea **16** through the seawater supply pipe **24** to the water chamber **2** of the cooling system **100**. The water pump **120** can, for example, be the hydraulic pump of the reverse osmosis plant configured for pumping seawater through various modules **350** of the plant **35** used for reverse osmosis.

5 The water outlet **5** of the solar panel assembly **101** is hydraulically coupled to a water release pipe **17** connected to a general water supply pipe (not shown) through various possible types of manifolds. Thus, when desired, the heated water can be released from the water chamber **2** through the water release pipe **17** and used for general consumption.

 As shown in **Fig. 17**, this configuration of the integrated system includes a one-way
10 valve **13** located within the water supply pipe **24** that ensures that the reverse osmosis plant **35** remains filled with water at all times, even when the water pump **120** is switched off.

 It should be understood that application of the cooling system, together with the solar panel assembly **101**, considerably increases the efficiency of the reverse osmosis plant **35**. Indeed, renewable energy is being used to power the plant and also the cool water coming
15 out of the plant is being used to maintain the solar panel assembly **1** at low temperatures, thus allowing for higher photovoltaic conversion efficiency.

 As such, those skilled in the art to which the present invention pertains, can appreciate that while the present invention has been described in terms of preferred embodiments, the concept upon which this disclosure is based may readily be utilized as
20 a basis for the designing of other structures, systems and processes for carrying out the several purposes of the present invention.

 Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

 Finally, it should be noted that the word “comprising” as used throughout the
25 appended claims is to be interpreted to mean “including but not limited to”.

 Reference numerals appearing in the claims are by way of illustration only and shall have no limiting effect on the scope of the claims.

 It is important, therefore, that the scope of the invention is not construed as being limited by the illustrative embodiments set forth herein. Other variations are possible within
30 the scope of the present invention as defined in the appended claims. Other combinations and sub-combinations of features, functions, elements and/or properties may be claimed through amendment of the present claims or presentation of new claims in this or a related application. Such amended or new claims, whether they are directed to different

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combinations or directed to the same combinations, whether different, broader, narrower or equal in scope to the original claims, are also regarded as included within the subject matter of the present description.

CLAIMS:

1. A cooling system (100) for cooling a solar panel assembly (101) including at least one photovoltaic (PV) module (1) having a plurality of solar cells generating electrical power and a PV junction box (9) attached to the back of the photovoltaic (PV) module,
- 5 the cooling system comprising:
- a solar panel frame (18) including a frame wall (181) having a panel holder (182) holding the solar panel assembly (101) at an upper part of the frame wall (181), and frame base ledges (183) projecting from opposite sides of the frame wall (181) of the solar panel frame (18) at a lower part of the frame wall (181);
- 10 a bottom plate (3) hermetically attached to the frame base ledges (183) to create a water chamber (2) directly underneath the PV module (1) of the solar panel assembly (101) for holding water for cooling the PV module (1); the water chamber (2) being defined by a back sheet (102) of the PV module (1), the frame wall (181) and the bottom plate (3); the water chamber (2) including a water inlet (4) arranged in the frame wall
- 15 (181) at one end of the chamber (2) and a water outlet (5) arranged in the frame wall (181) at the opposite end of the chamber (2) along the length of the solar panel frame;
- a stream spreader (7) arranged within the water chamber (2) and hydraulically coupled to the inlet (4) on an inner surface of the frame wall (181), and configured to provide a uniform fluid dynamic within the water chamber (2);
- 20 a pipe adapter (6) hydraulically coupled to the water outlet (5) on an outer surface of the frame wall (181), and configured to provide a freedom of movement of the solar panel assembly (101) that is required for tilting the solar panel assembly (101) at such an installation angle with respect to a surface of an installation platform when the water in the water chamber (2) is in complete contact with the back sheet (102) of the PV module
- 25 (1);
- a temperature sensor (8) attached to the back sheet (102) of the PV module (1), and configured to generate a temperature sensor signal representative of the temperature of the PV module (1) at the back sheet (102) of the PV module; the temperature sensor (8) and the PV junction box (9) attached to the back sheet (102) of the PV module (1)
- 30 being located within the water chamber (2) and being sealed off by a waterproof material;
- an external PV junction box (10) mounted outside of the water chamber (2), and electrically connected to the PV junction box (9) and to the temperature sensor (8) located

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within the water chamber (2) so as to provide easy accessibility to electrical terminals of the PV module and the temperature sensor (8).

2. The cooling system of claim 1, wherein the solar panel frame (18) includes an upper top ledge (187) and a lower top ledge (186) projecting from opposite sides of the frame wall (181) of the solar panel frame (18) at an upper part of the frame wall (181), wherein the panel holder (182) is an integrated part of the frame wall (181) and includes a slot (180) formed by the upper and lower top frame ledges (187) and (186) adapted to hold the solar panel assembly (101).

3. The cooling system of claim 1, the solar panel frame (18) includes a lower top ledge (186) projecting from opposite sides of the frame wall (181) of the solar panel frame (18) at an upper part of the frame wall (181), wherein the panel holder (182) is a separate part of the frame wall (181) attached to the frame wall (181), wherein the panel holder (182) includes an upper top ledge (187) forming, together with the lower top ledge (186), a slot (180) adapted to hold the solar panel assembly (101).

4. The cooling system of claim 1, wherein the bottom plate (3) is made of material selected from at least one of aluminum, stainless steel, polyethylene terephthalate (PET), Polypropylene and Polyimide.

5. The cooling system of claim 1, wherein the stream spreader (7) includes an assembly of a T-elbow joint connected to the water inlet (4) at one end, and two 45° elbow joints connected to two other ends of T-elbow joint, correspondingly; the openings of the two 45° elbow joints are directed towards an inner face of the frame wall (181).

6. The cooling system of claim 1, wherein the pipe adapter (6) includes two 90° elbow joints.

7. The cooling system of claim 1, wherein the water chamber (2) is created by attaching the bottom plate (3) to an outer surface (184) of the frame base ledges (183) of the solar panel frame (18).

8. The cooling system of claim 1, wherein the water chamber (2) is created by attaching the bottom plate (3) to an inner surface (185) of the frame base ledges (183) of the solar panel frame (18).

9. The cooling system of claim 1, wherein the frame base ledges (183), which project from the longitudinal sides of the solar panel frame (18), are connected together to form the bottom plate (3) that is integrated with the frame wall (181).
10. The cooling system of claim 1, further including a solid water tank (26) forming the water chamber (2), the water tank (26) fitted directly into a gap at the back of the solar panel frame (18).
11. The cooling system of claim 1, further including an inflatable water tank (27) forming the water chamber (2); wherein the inflatable water tank (27), when inflated, is fitted directly into a gap at the back of the solar panel frame (18), and fixed to the back sheet of the solar panel assembly (101).
12. The cooling system of any one of claims 1 to 11, wherein the cooling system is installed on an installation surface at a predetermined installation angle with respect to the installation surface; the water inlet (4) of the solar panel assembly (101) is arranged in the frame wall (181) at the bottom of the solar panel frame (18) and is hydraulically coupled to a local water supply pipe (24); the water outlet (5) of the solar panel assembly (101) is arranged in the frame wall (181) at the top of the solar panel frame (18) and is hydraulically coupled to a water release pipe (17) coupled to a general water supply pipe.
13. The cooling system of any one of claims 1 to 11, wherein the cooling system is installed on an installation surface at a predetermined installation angle with respect to the installation surface; the water inlet (4) is arranged in the frame wall (181) at the top of the solar panel frame (18) and is hydraulically coupled to a local water supply pipe (24); the water outlet (5) of the solar panel assembly (101) is arranged in the frame wall (181) at the bottom of solar panel frame (18) and is hydraulically coupled to a water release pipe (17) coupled to a general water supply pipe.
14. The cooling system of any one of claims 1 to 11, wherein the cooling system is installed on an installation surface at a predetermined installation angle with respect to the installation surface; wherein the cooling system (100) further includes a water heating system (22) installed on the roof (20) of the building (21) and is hydraulically coupled to the water outlet (5) of the solar panel assembly (101) through a pipe (170); the water inlet (4) of the solar panel assembly (101) is hydraulically coupled to the local water supply pipe (24).

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15. The cooling system of any one of claims 1 to 11, wherein the cooling system is installed on an installation surface at a predetermined installation angle with respect to the installation surface, wherein the cooling system (100) further includes:

a water storage tank (19) installed on the installation surface;

5 a controllable water pump (12) arranged in a manifold (171) hydraulically coupling the water storage tank (19) to the water inlet (4) of the solar panel assembly (101); the controllable water pump (12) is configured for regulating a flow rate of egress of the water from the water storage tank (19) passing into the water chamber (2);

a control unit (14) is operatively coupled to the controllable water pump (12), and
10 is configured for controlling operation thereof for supply of cold water from the water storage tank (19); the control unit (14) is electrically coupled to the temperature sensor (8) attached to the back sheet (102) of the PV module (1) via the PV junction box (9) and via the external PV junction box (10) mounted outside of the water chamber (2); the control unit (14) is responsive to the temperature sensor signal generated by the
15 temperature sensor (8), and is capable of generating control signals for controlling operation of the controllable water pump (12) by switching it “on” or “off”, thereby providing a pulsed supply of water from the water storage tank (19) into the water chamber (2); and

a one-way valve (13) located within the manifold (171) between the water storage
20 tank (19) and the water storage tank (19), thereby to ensure that the water chamber (2) remains permanently filled with water.

16. The cooling system of any one of claims 1 to 11, wherein the cooling system is installed on water on a platform at a predetermined installation angle with respect to a surface of the platform, wherein the cooling system (100) further includes:

25 a controllable water pump (12) hydraulically coupled to the water inlet (4) through a manifold, and configured to controllably pump water to the water chamber (2) through the water inlet (4) arranged in the frame wall (181) at the bottom of the solar panel frame (18), and to push the water heated in the water chamber (2) to a water release pipe (17) through the water outlet (5) arranged in the frame wall (181) at the top of the solar panel
30 frame (18); the controllable water pump (12) is configured for regulating a flow rate of ingress of the water into the water chamber (2);

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a control unit (14) operatively coupled to the controllable water pump (12), and is configured for controlling operation thereof for supply of water; the control unit is (14) electrically coupled to the temperature sensor (8) attached to the back sheet (102) of the PV module (1) via the external PV junction box (10) mounted outside of the water chamber (2); the control unit (14) is responsive to the temperature sensor signal generated by the temperature sensor (8), and is capable of generating control signals for controlling operation of the controllable water pump (12) by switching it “on” or “off”, thereby providing a pulsed supply of water into the water chamber (2); and

a one way valve (13) located within the water supply pipe (24), thereby to ensure that the water chamber (2) remains permanently filled with water.

17. The cooling system of any one of claims 1 to 11, wherein the cooling system is installed on water on a platform at a predetermined installation angle with respect to a surface of the platform, wherein the cooling system (**100**) further includes:

a controllable water pump (12) hydraulically coupled to the water inlet (4) through a manifold, and configured to controllably pump water to the water chamber (2) through the water inlet (4) arranged in the frame wall (181) at the top of the solar panel frame (18), and to push the water heated in the water chamber (2) to a water release pipe (17) through the water outlet (5) arranged in the frame wall (181) at the bottom of the solar panel frame (18); the controllable water pump (12) is configured for regulating a flow rate of ingress of the water into the water chamber (2);

a control unit (14) operatively coupled to the controllable water pump (12), and is configured for controlling operation thereof for supply of seawater; the control unit (14) is electrically coupled to the temperature sensor (8) attached to the back sheet (102) of the PV module (1) via the external PV junction box (10) mounted outside of the water chamber (2); the control unit (14) is responsive to the temperature sensor signal generated by the temperature sensor (8), and is capable of generating control signals for controlling operation of the controllable water pump (12) by switching it “on” or “off”, thereby providing a pulsed supply of seawater into the water chamber (2); and

a one way valve (13) located within the water supply pipe (24), thereby to ensure that the water chamber (2) remains permanently filled with water.

18. The cooling system of any one of claims 1 to 11, wherein the cooling system is integrated with a reverse osmosis plant.

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19. The cooling system of claim 1, wherein the cooling system is installed on a platform at a predetermined installation angle with respect to a surface of the platform; the water inlet (4) of the solar panel assembly (101) is arranged in the frame wall (181) at the bottom of the solar panel frame (18) and is hydraulically coupled to the reverse osmosis plant configured to receive seawater from the sea; the water outlet (5) of the solar panel assembly (101) is arranged in the frame wall (181) at the top of the solar panel frame (18) and is hydraulically coupled to a water release pipe (17).

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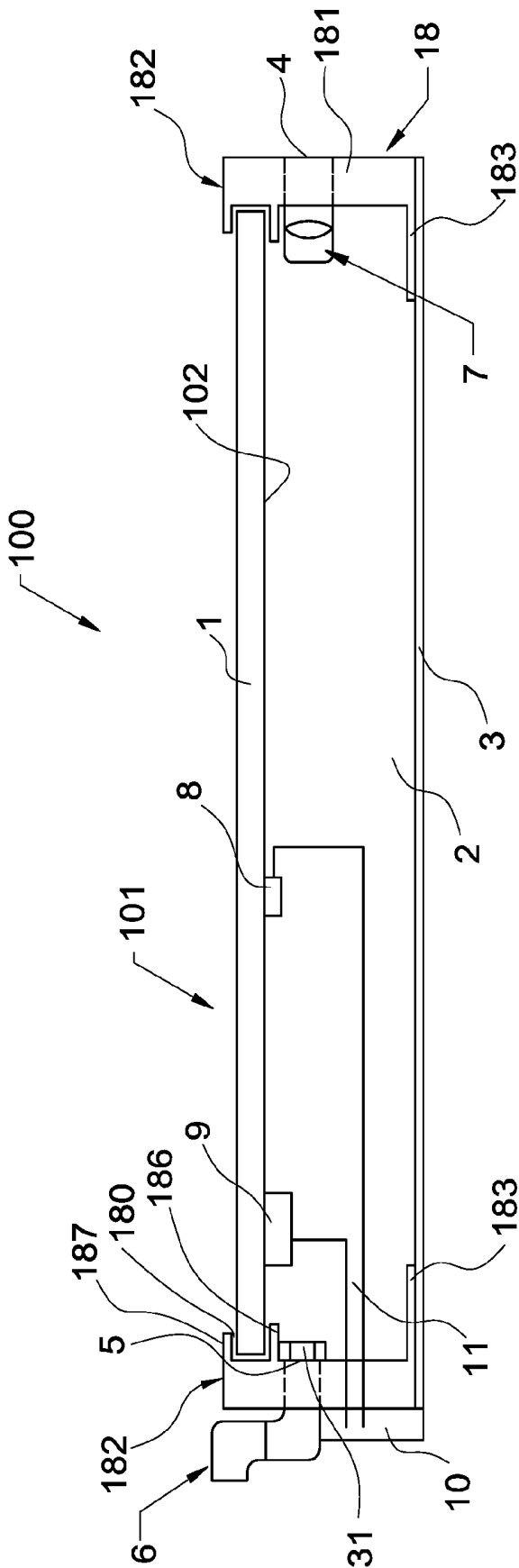


Fig. 1A

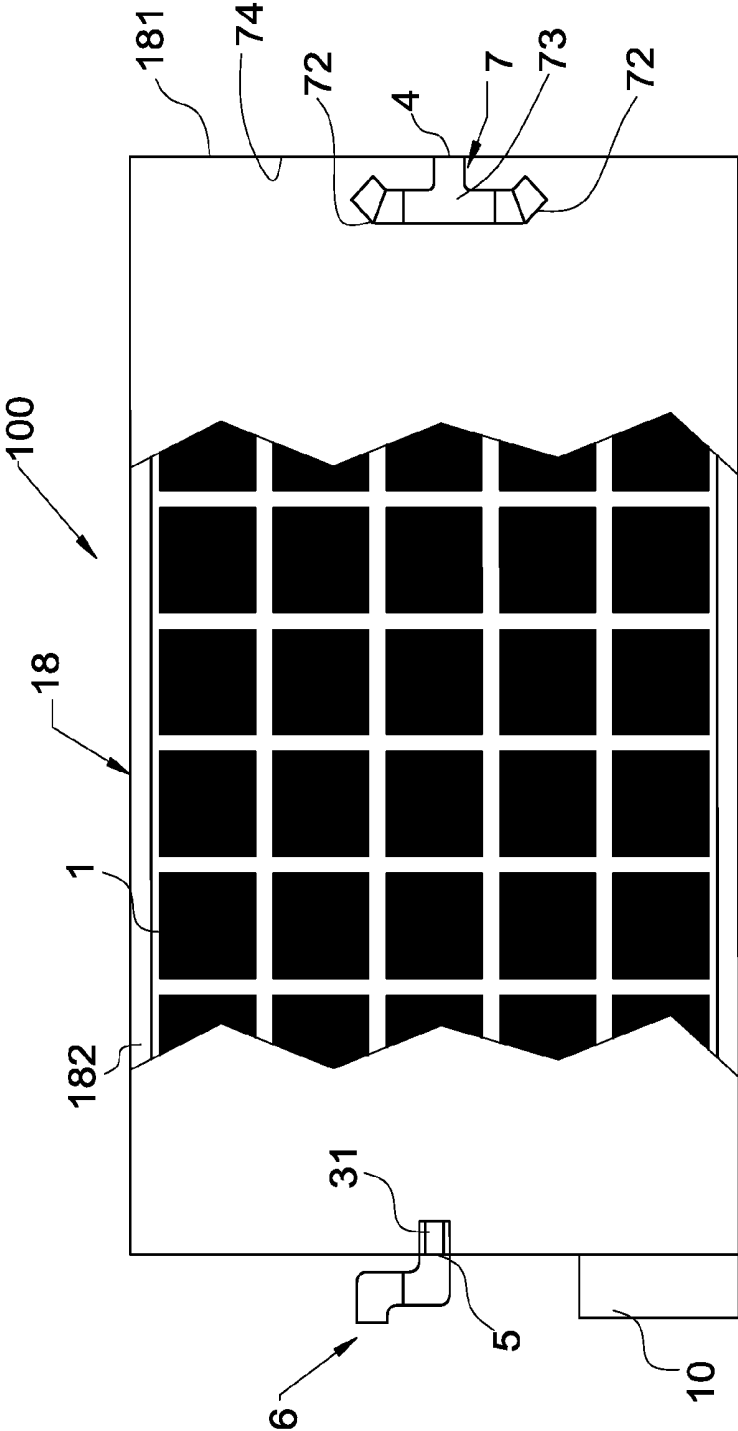


Fig. 1B

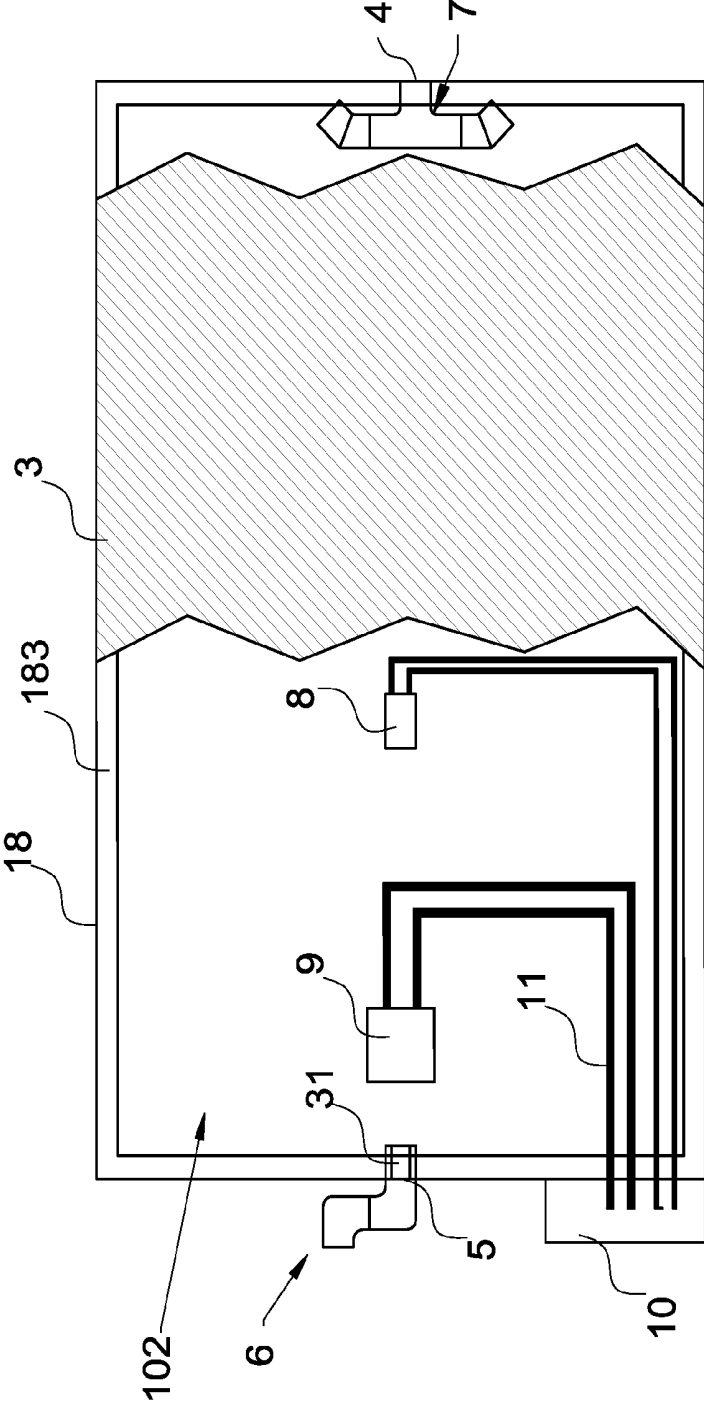


Fig. 1C

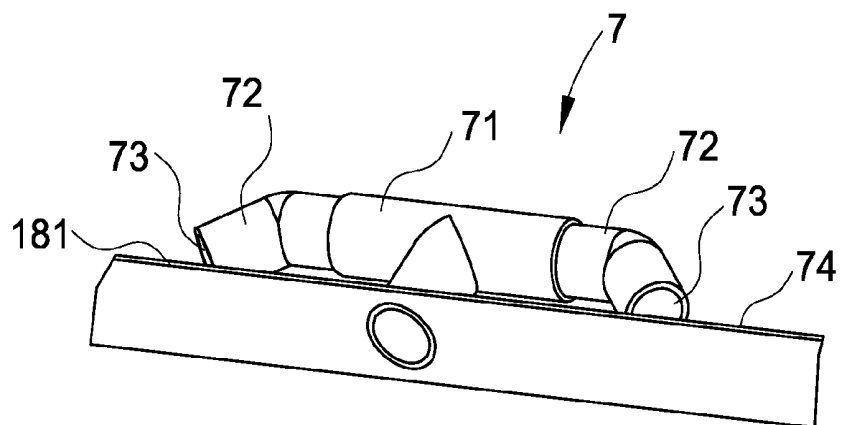


Fig. 2

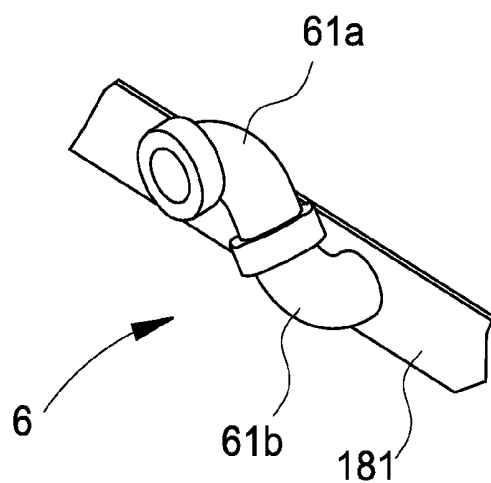


Fig. 3

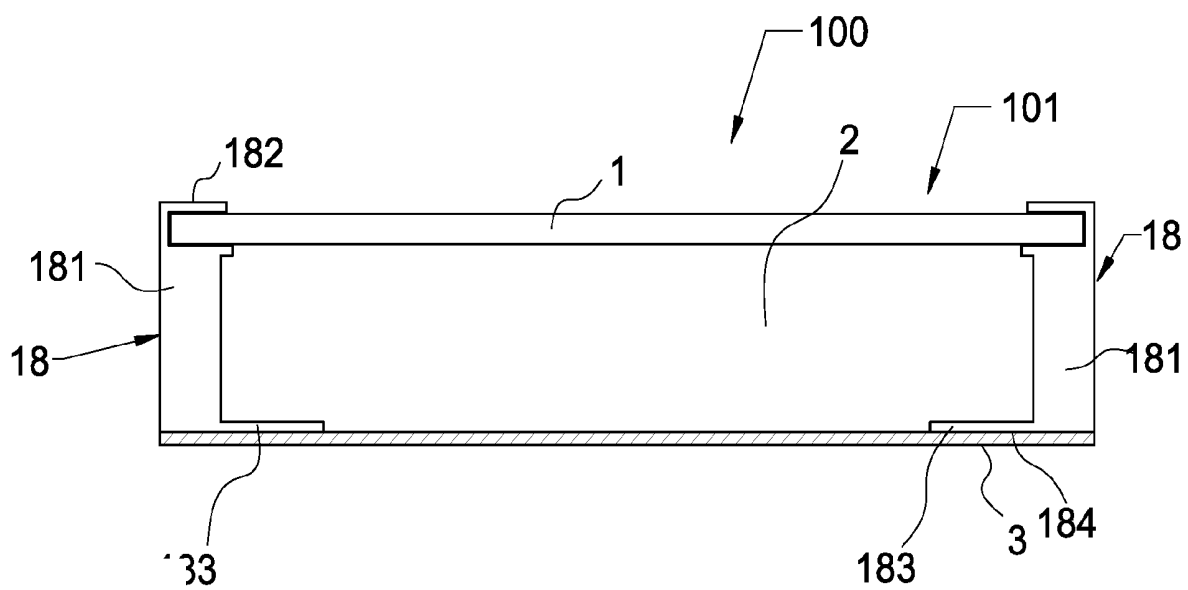


Fig. 4

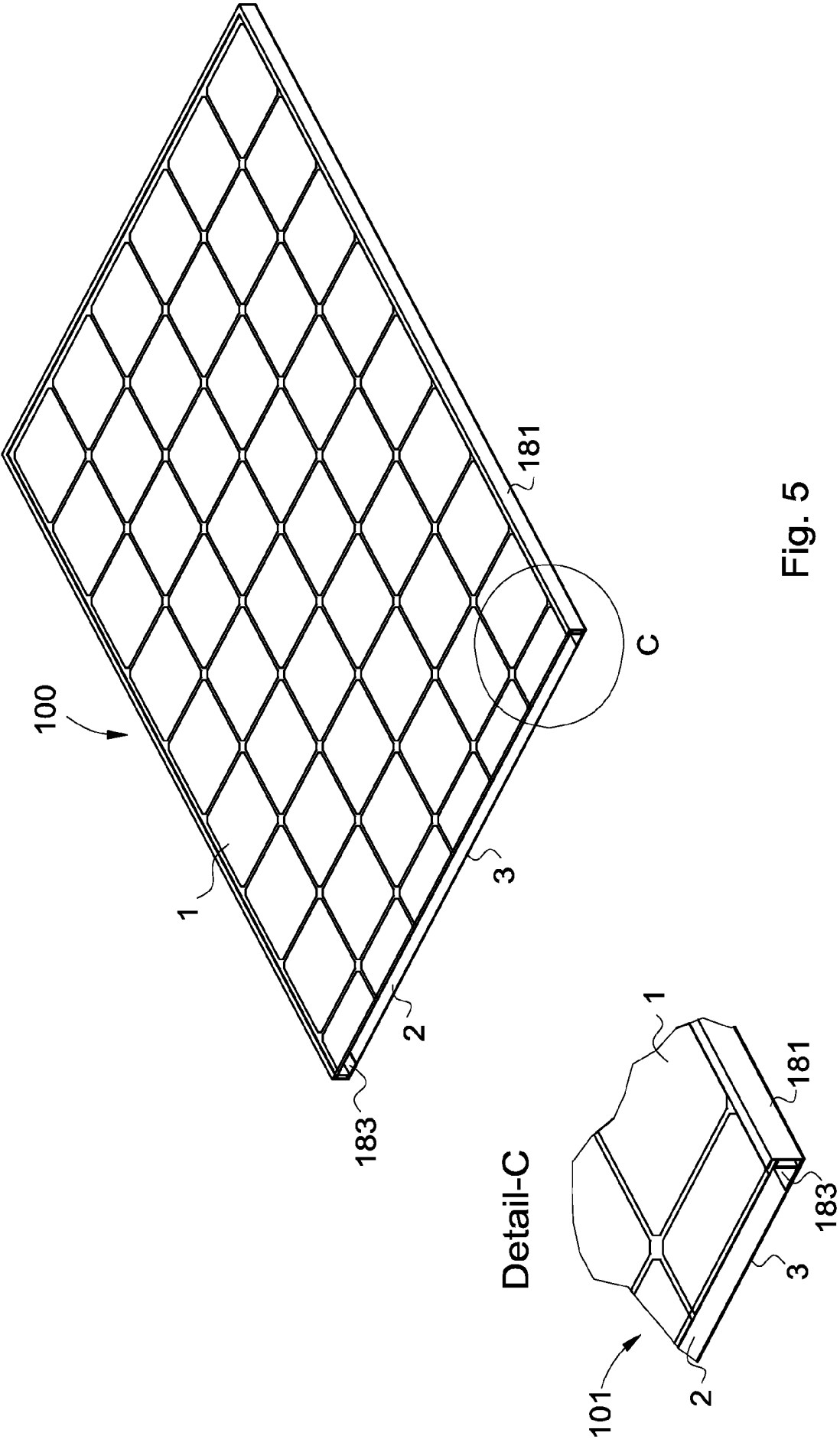


Fig. 5

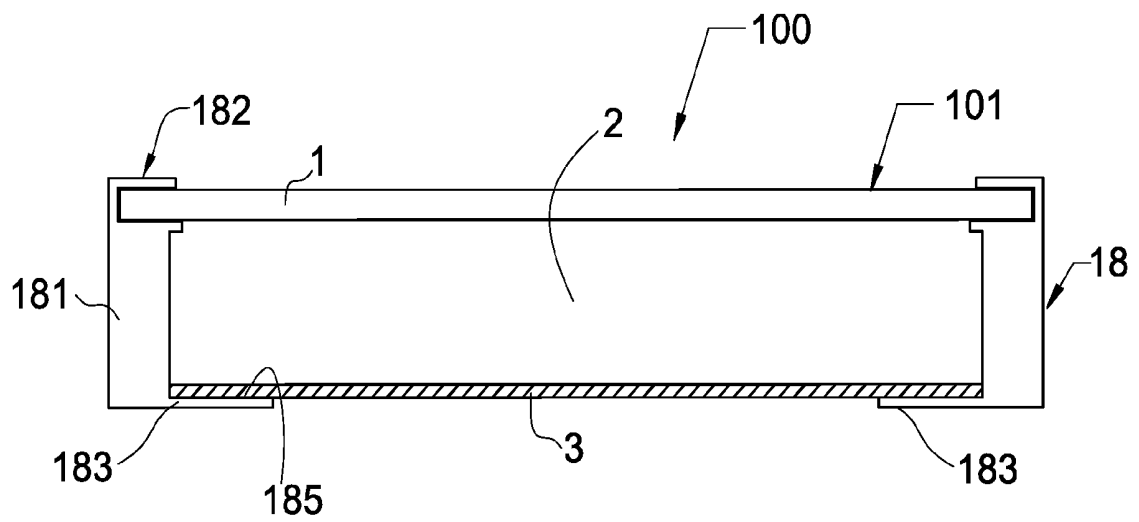


Fig. 6

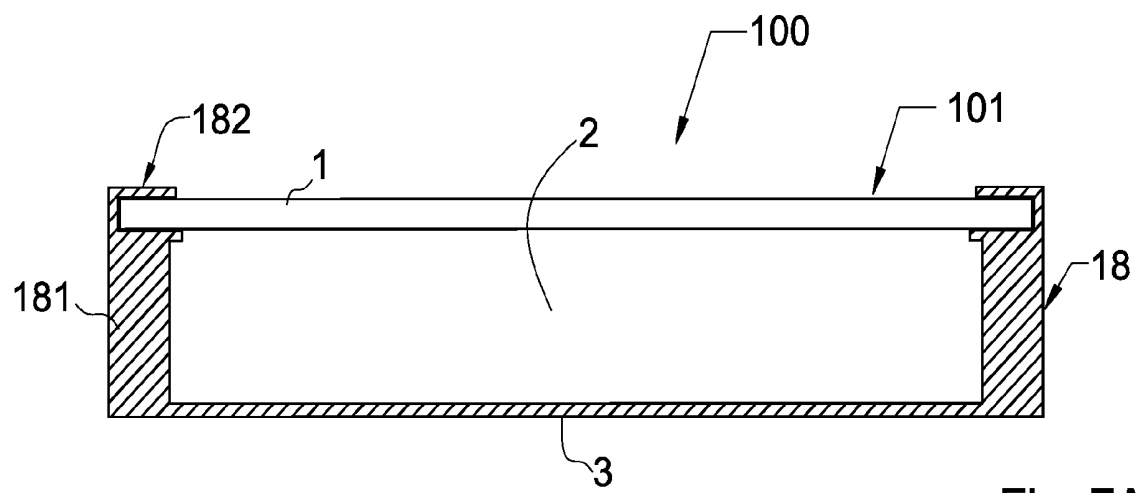


Fig. 7A

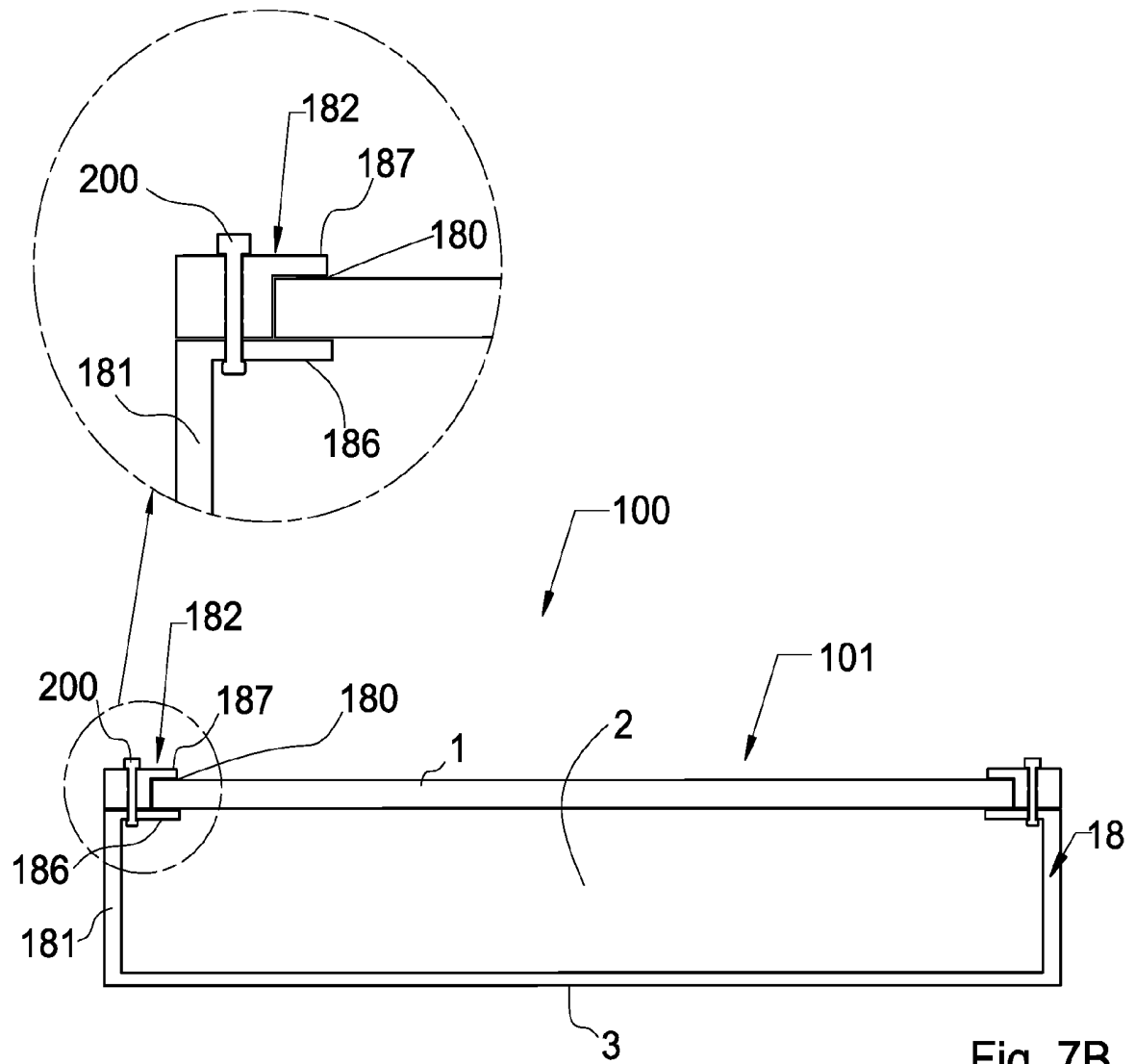


Fig. 7B

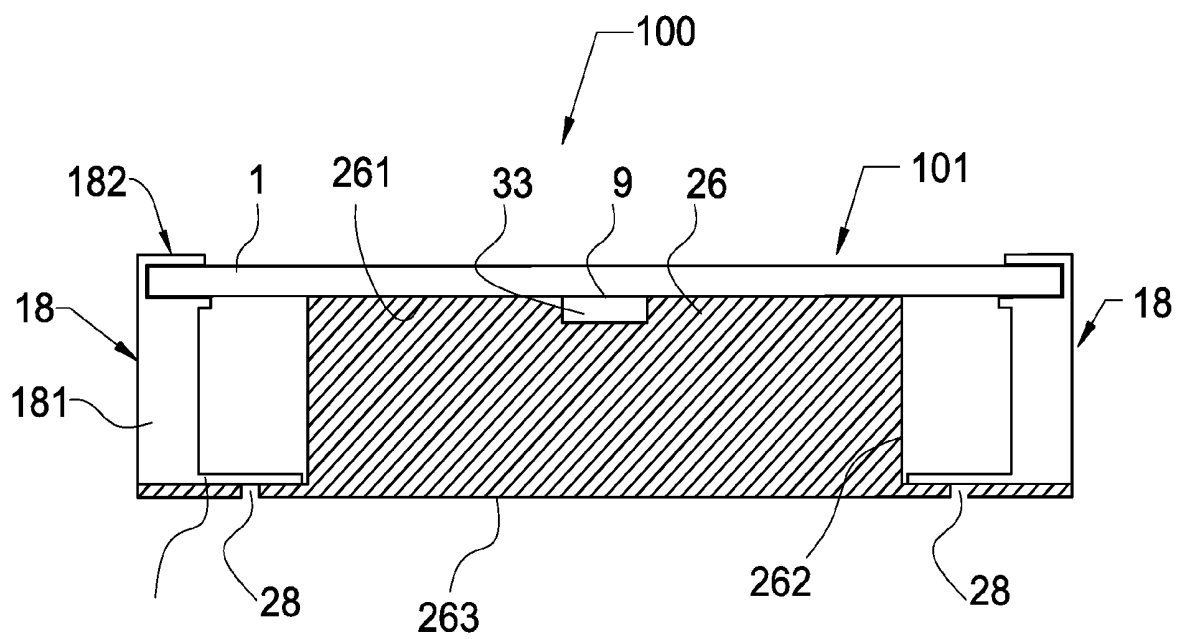


Fig. 8

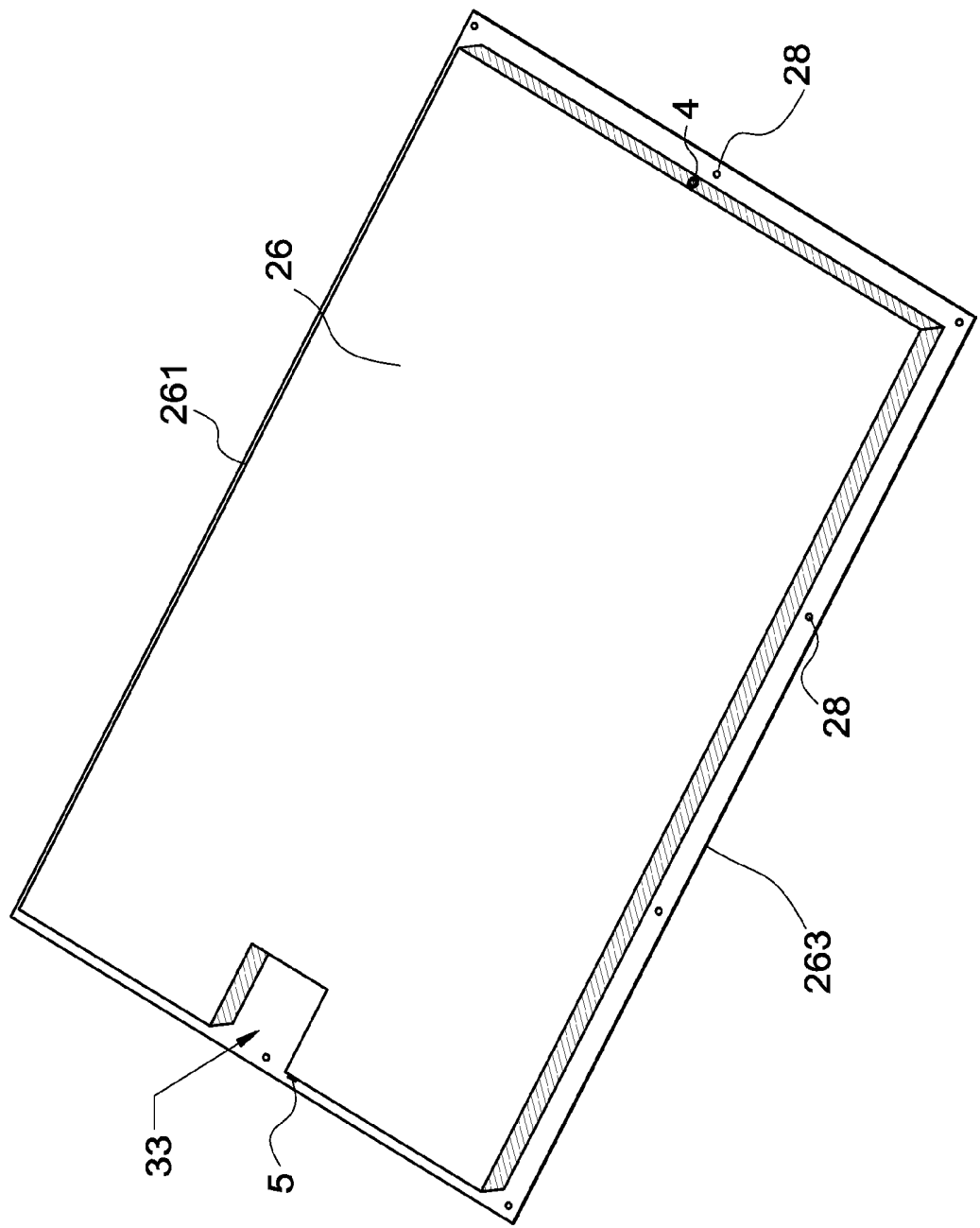


Fig. 9

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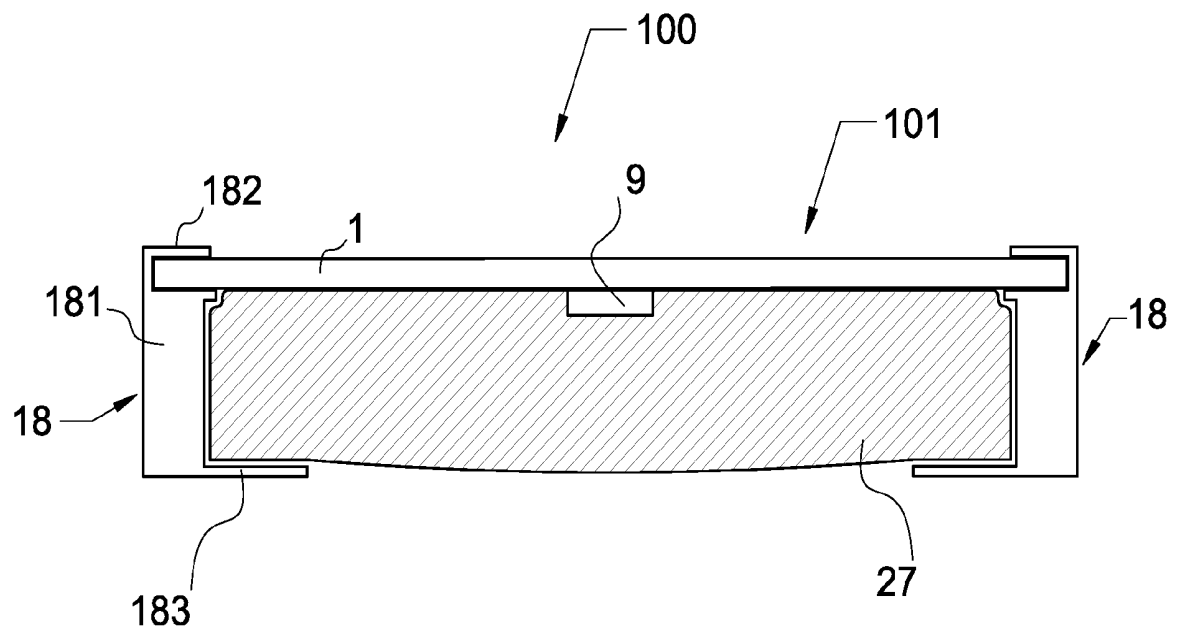


Fig. 10

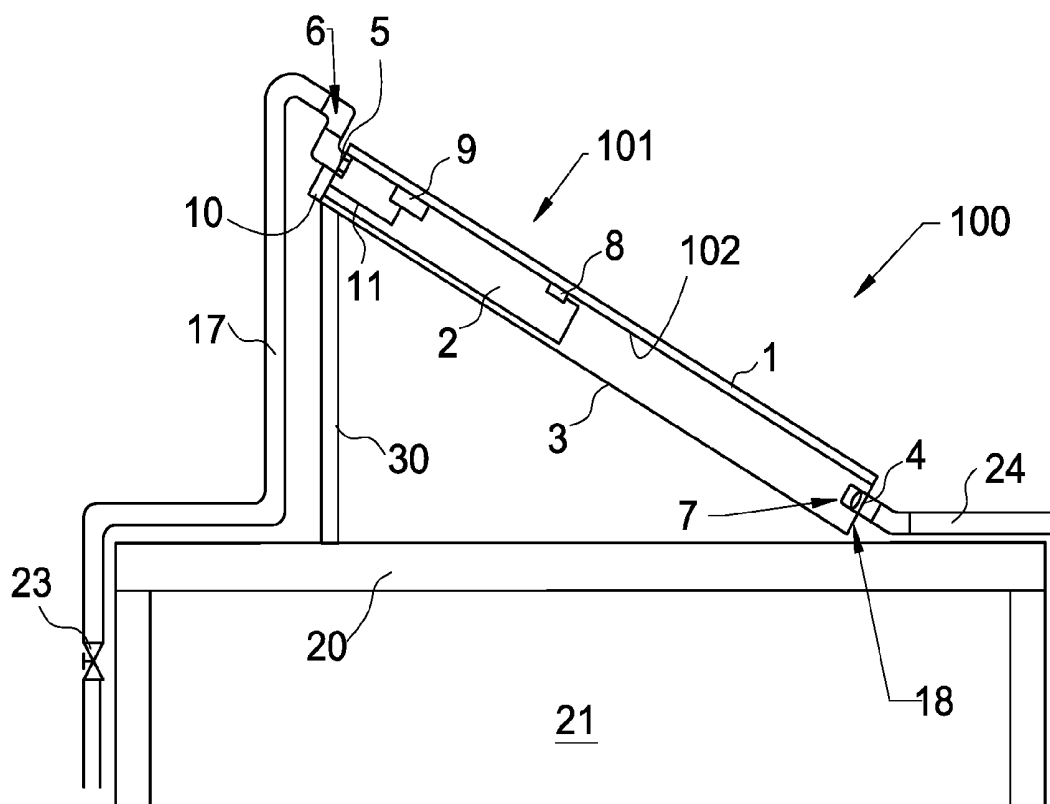


Fig. 11

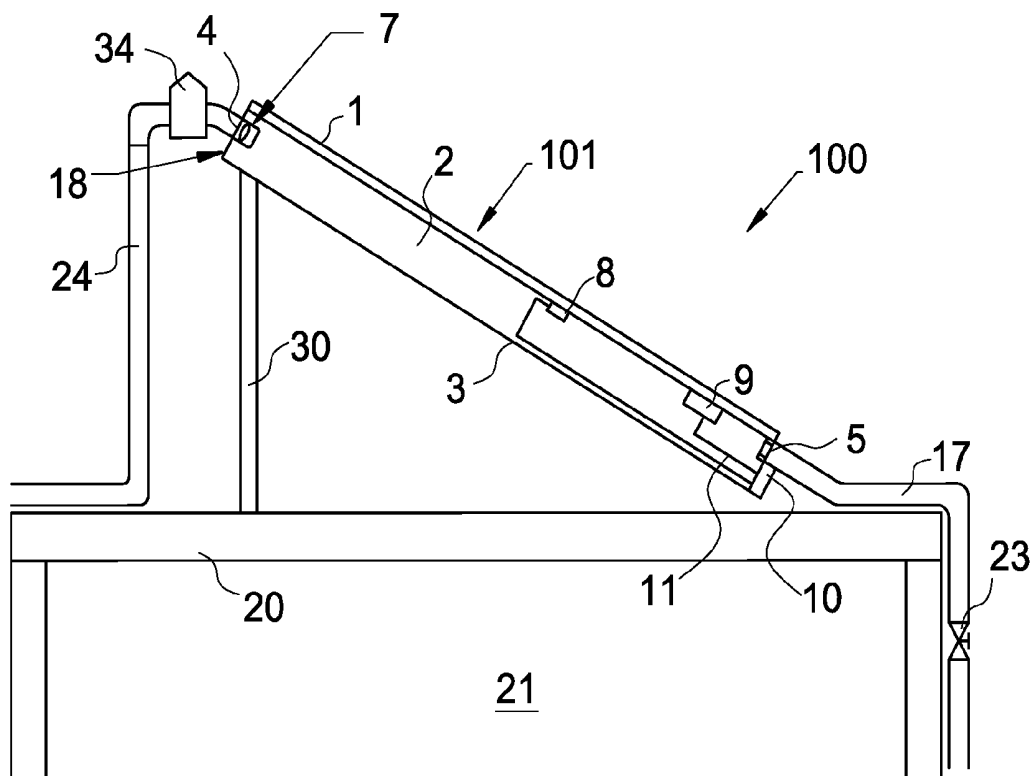


Fig. 12

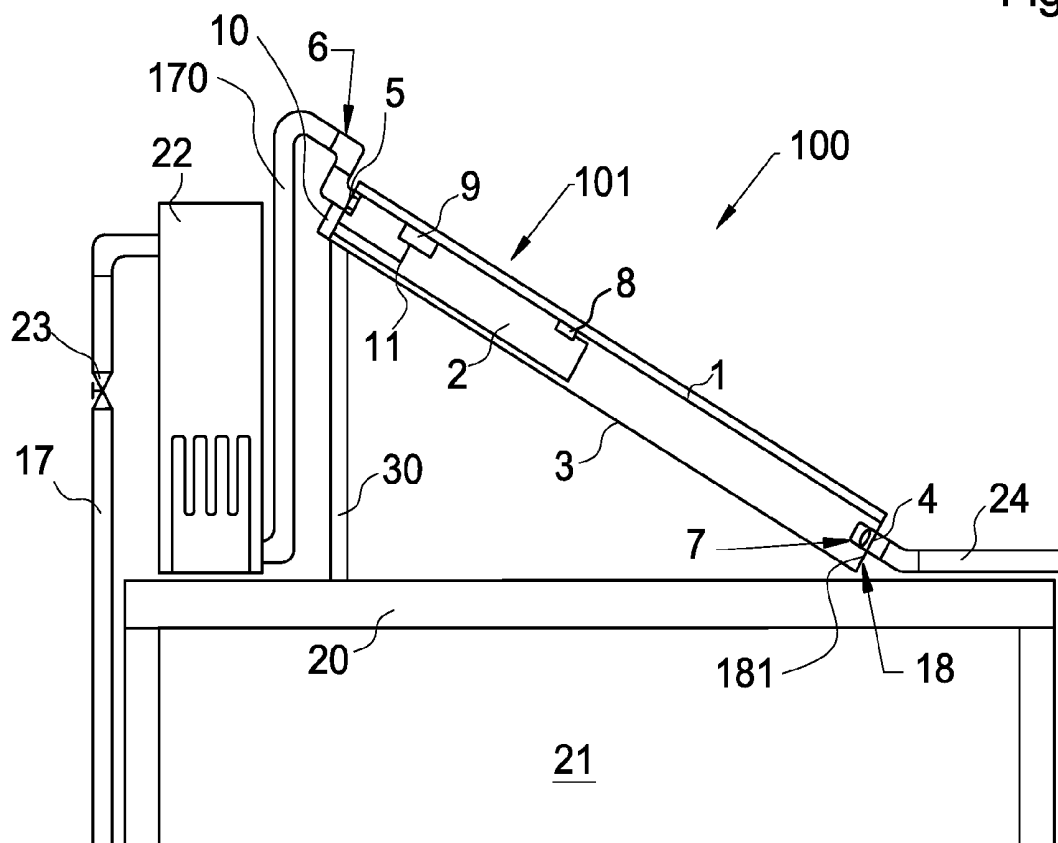


Fig. 13

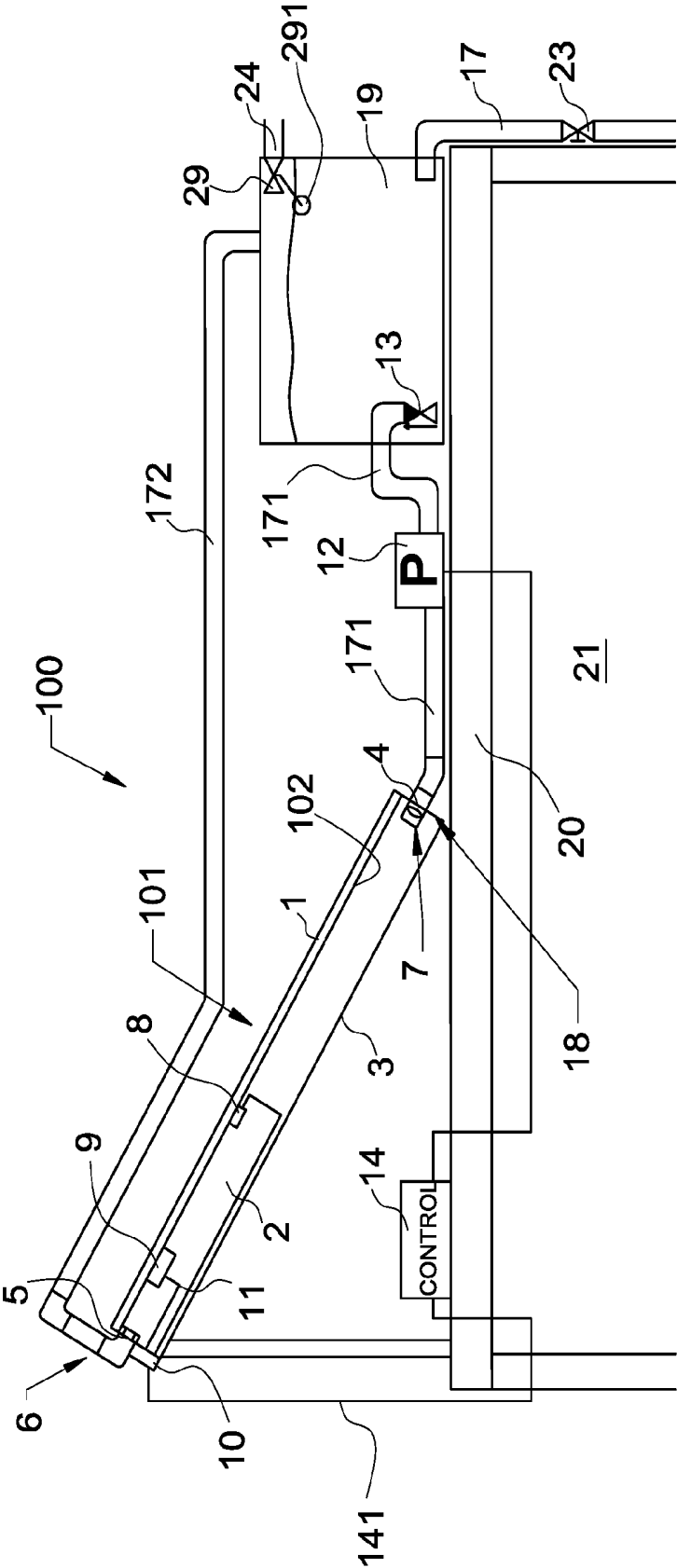


Fig. 14

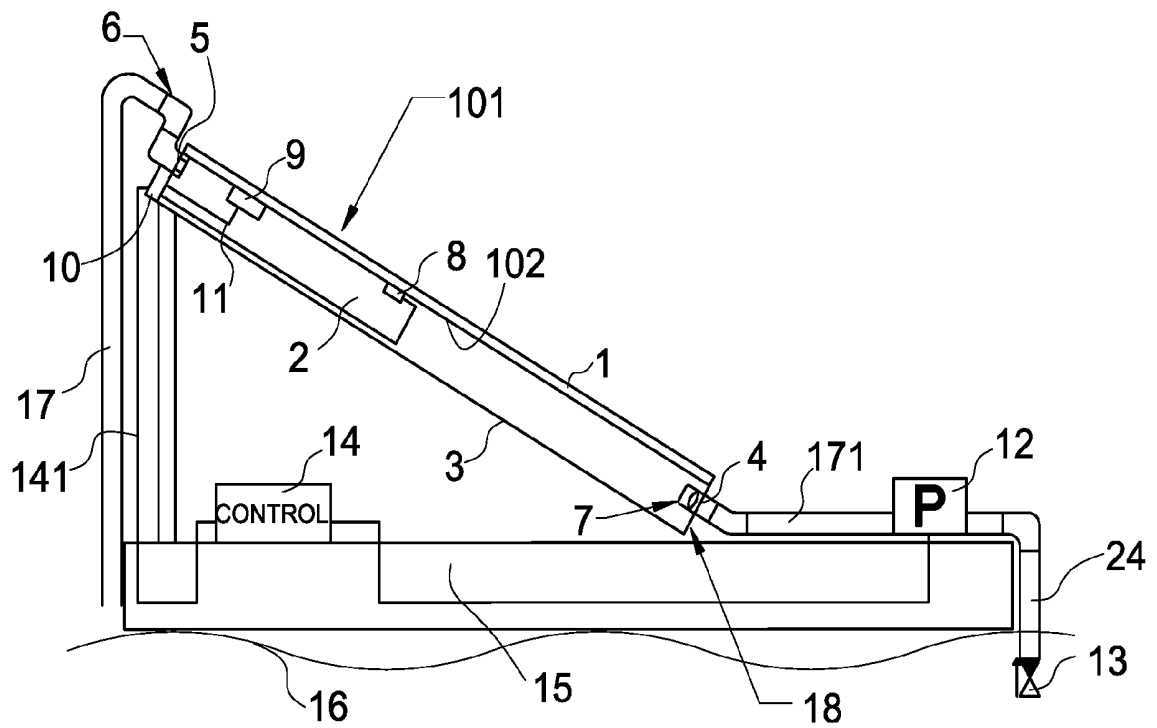


Fig. 15

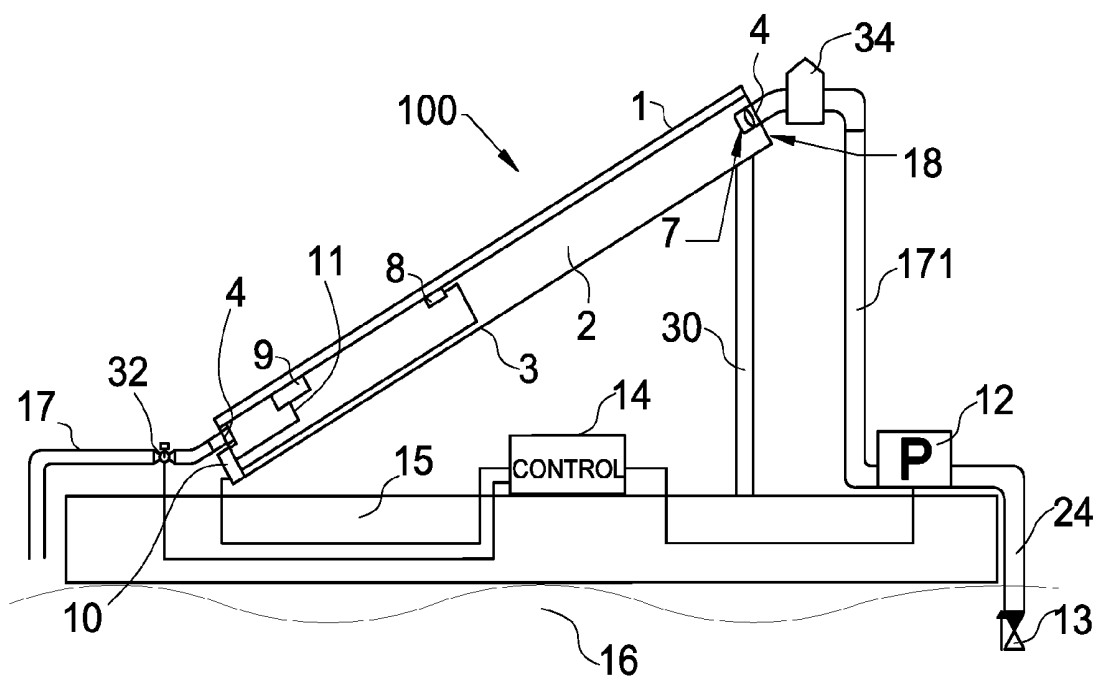


Fig. 16

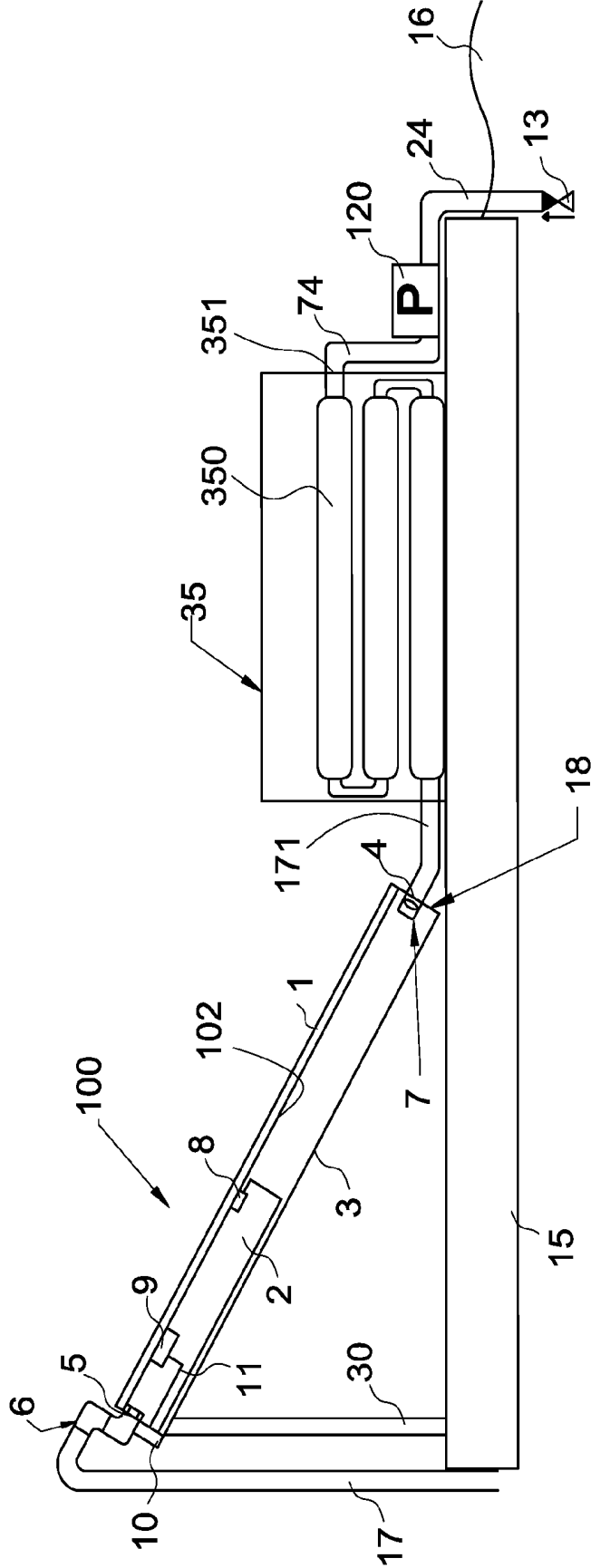


Fig. 17

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2022/050897

A. CLASSIFICATION OF SUBJECT MATTER**H02S 40/42**(2022.01)i; **H02S 30/10**(2022.01)i; **H01L 31/052**(2022.01)i

CPC:H02S 40/42; H02S 30/10; H01L 31/0521

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)

H02S 40/42; H02S 30/10; H01L 31/052

CPC:H02S 40/42; H02S 30/10; H01L 31/0521

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)

Databases consulted: Esp@cenet, Orbit, Similari (AI-based)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 103094391 A (EGING PHOTOVOLTAIC TECH. CO. LTD.) 08 May 2013 (2013-05-08) The whole document	1-19
A	CN 206251050 U (UNIV. GUANGXI) 13 June 2017 (2017-06-13) The whole document	1-19

☐ 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

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“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

“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

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

18 September 2022

Date of mailing of the international search report

18 September 2022

Name and mailing address of the ISA/IL

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Authorized officer

BRAVDO Roni

Telephone No.

INTERNATIONAL SEARCH REPORT
on on patent family members

International application No.

PCT/IL2022/050897

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	103094391	A	08 May 2013	CN	103094391	A	08 May 2013
				CN	103094391	B	08 June 2016
CN	206251050	U	13 June 2017	CN	206251050	U	13 June 2017