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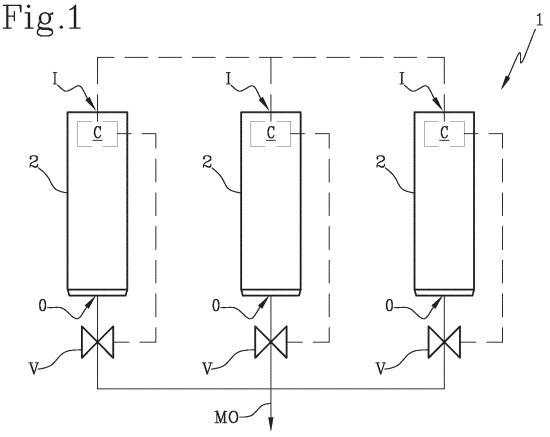
(54) WATER HEATING SYSTEM AND METHOD

(57) A water heating system (1) comprises: a plurality of heat pump units (2), each of which includes: a water tank (T); a solenoid valve (V) located at a water outlet (O) (or inlet); a temperature sensor (S); a control unit (C). The control units are interconnected through a bus and are programmed so that one of the heat pump units (2) acts as a master unit (2A) and the remaining units act as slave units (2B). The master unit is configured to derive an operative number responsive to a hot water demand, to turn on one or more heat pump units (2) based on the derived operative number, and to activate the solenoid valve of one or more of the heat pump units, responsive to the hot water demand. The units turned on operate in an ON mode in which the heat pump is active to heat the water in the tank (T).

Fig.1



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Description

[0001] This invention relates to a water heating system and to a water heating method.

[0002] In prior art water heating systems, the demand for a quantity of hot water is satisfied using heat pump units having different thermal power ratings. The heat pumps extract the heat from a source, such as outside air, and then amplify and transfer the heat where required. The heat pump units include a compressor, an evaporator, a condenser and an expansion valve, which form a cycle whereby a refrigerant is moved. When the hot water demand is particularly high, two or more heat pump units are connected in parallel because a single heat pump cannot deliver the power required. Traditionally, in water heating systems with a plurality of heat pump units in parallel, all the units in parallel are turned on simultaneously.

[0003] That method has some disadvantages, however; for example, it is difficult to control the operating state of all the heat pump units when they are all working at the same time.

[0004] Moreover, in that method, it is not possible to determine the number of units that need to be activated to satisfy the real hot water demand; that means a lot of energy is wasted.

[0005] In this context, patent document CN202403412 describes an energy-saving heat pump system in which a master control unit is connected to a slave heat pump unit through a master-slave communication system. However, that document does not provide further details as to how the slave unit is controlled by the master control system.

[0006] Furthermore, patent document CN104748393 describes a heat pump system having a plurality of heat pumps connected to each other.

[0007] The plurality of units comprises a main unit having a main controller and a plurality of sub-units having a plurality of secondary controllers. After receiving the power-on signal, the main controller detects a working condition parameter of the water tank and determines whether the working condition parameter of the water tank satisfies the first preset power-on condition. If the working condition parameter of the tank meets the first power-on condition, the main controller detects whether the working condition parameter of the total flow path meets the second preset power-on condition and, if the working condition parameter of the total flow path meets the third preset power-on condition, the main controller sends a power-on command to the plurality of secondary controllers; each of the secondary controllers detects a working condition parameter of a branch corresponding to it and determines whether the working condition parameter of the branch meets the third preset power-on condition; if the working condition parameter of the branch meets the third preset power-on condition, the heat pump corresponding to the branch is started. Furthermore, patent document CN 107 062 589 A describes a water heating system comprising a plurality of heat pumps, where each heat pump unit includes: a water tank, in which the heat pump unit is operable in an ON mode, in which the heat pump is active to heat the water in the tank, and an OFF mode, in which the heat pump is inactive; a water inlet and a water outlet in communication with each other to form a main water outlet; a solenoid valve at the water outlet or at the water inlet; a temperature sensor; a control unit, connected to the solenoid valve and to the temperature sensor; and a bus, where the control units are interconnected by the bus to exchange data.

[0008] However, the water heating pump systems of the prior art have some disadvantages and can be improved. In effect, there are several needs in this field.

[0009] One need is to provide a water heating system capable of supplying the required quantity of hot water with greater efficiency and reliability. Another need is to improve the water heating system by extending its working life. Another need is to provide a water heating system that is more energy efficient.

[0010] The aim of this disclosure is to provide a water heating system and a water heating method to overcome the above mentioned disadvantages of the prior art.

[0011] This aim is fully achieved by the system and method of this disclosure as characterized in the appended claims.

[0012] According to an aspect of it, this disclosure provides a water heating system. The water heating system (or the system for short) comprises a plurality of heat pump units. Each heat pump unit (or each unit for short) includes a water tank. Each heat pump unit operates in an ON mode and in an OFF mode. In the ON mode, the heat pump is active to heat the water in the tank. In the OFF mode, the heat pump is inactive. Each unit includes a water inlet. Each unit includes a water outlet. The water outlets of the units are in communication with each other to form a main water outlet.

[0013] Each unit may include a solenoid valve. The solenoid valve is located at the water outlet or at the water inlet. Each unit includes a temperature sensor. The temperature sensor is configured to detect the temperature of the water inside the water tank.

[0014] Each unit includes a control unit. The control unit is connected to the solenoid valve. The control unit is connected to the temperature sensor.

[0015] In an example, the water heating system comprises a bus. The control units are interconnected through the bus to exchange data. The heat pump units may be interconnected using different buses, for example, CAN-bus or Profibus.

[0016] The control units are programmed so that one of the heat pump units acts as a master unit and the remaining units act as slave units.

[0017] The master unit is programmed to derive an operative number. The operative number is derived in response to a hot water demand. The operative number is the required number of heat pump units working in ON

mode needed to satisfy the hot water demand. The master unit is configured to turn on one or more heat pump units based on the derived operative number. The master unit is also configured to activate the solenoid valve of one or more of the heat pump units. The master unit activates the solenoid valve of one or more of the heat pump units responsive to the hot water demand.

[0018] Therefore, according to an aspect of this disclosure, the slave units are controlled by the master unit and the master unit derives the number of units which must operate in the ON mode to satisfy the hot water demand. Furthermore, the number of active valves corresponds to the number of units which are ON. This solution provides higher energy efficiency because the master unit turns on only the number of units needed to meet the hot water demand. It should be noted that the open valves may belong to the units working in the ON mode or to those in the OFF mode. Moreover, the fact that each unit includes a solenoid valve allows preventing the cold water that may be present in the unit from being mixed with the hot water available in the other units.

[0019] In an example, all the heat pump units have the same hardware.

[0020] The master unit is configured to receive data relating to the temperature of the water tank of each heat pump unit. The master unit is also configured to activate the solenoid valves of the heat pump units with the highest detected water tank temperature.

[0021] According to this solution, only the solenoid valves of the units with the highest detected temperature (in which the tank contains water with the highest temperature) are activated, even if these units are not ON; this solution thus allows having a water heating system that is more reliable and more efficient, capable of providing the hot water required.

[0022] In another example, the master unit may be configured to open the solenoid valves based on other criteria.

[0023] In an example, the heat pump units are connected in parallel. The master unit may be configured to associate a ranking code with each heat pump unit. The master unit may also be configured to turn on the heat pump units, sequentially, as a function of the ranking code of each unit, for a predetermined time interval.

[0024] Furthermore, at the end of the predetermined time interval, the master unit is configured to assign the ranking code of each heat pump unit to the adjacent one.

[0025] The master unit may be configured to turn on the heat pump units based on the ranking code and starting from the smallest ranking code.

[0026] Therefore, according to an aspect of this disclosure, in each interval (predefined minutes, hours or days), at least one of the units that was in the ON mode in the previous interval remains inactive in the OFF mode: all the units have the same wear rate, thus increasing the working life of the system. It should be noted that if all the heat pump units need to be in operation in a particular interval, none of the units remains inactive in the OFF mode.

[0027] It should be noted that this disclosure also contemplates an example in which the units may be switched on sequentially based on their ranking code, and the solenoid valves are not necessarily the solenoid valves of the units with the highest detected temperature (as explained above) but they may be chosen by the master unit based on other criteria.

[0028] The heat pump units each possess a serial code. The serial code is unique for each heat pump unit. Moreover, the serial code is always the same for each heat pump unit. In an example, the master unit is programmed to detect the serial code of each heat pump. The master unit uses the serial code as an identification code. In an example, for each heat pump unit, the serial code and the corresponding ranking code are stored in a database. The serial codes and the corresponding ranking codes may be stored in a memory of the control unit of the master unit. The serial codes and the corresponding ranking codes stored in the database determine the sequence according to which the heat pump units are turned on by the master unit. Furthermore, the ranking codes associated with the serial codes may be modified dynamically as a function of one or more predetermined criteria. The predetermined criteria may be, for example: the number of hours or days of operation, or the number of times each heat pump unit has been switched on.

[0029] In an example, the master unit is configured to detect faulty heat pump units. The master unit is configured to assign the ranking code of a faulty unit to the unit adjacent to it.

[0030] This solution allows obtaining a system that is capable of delivering the required amount of hot water in a reliable manner.

[0031] In an example, the number of activated solenoid valves corresponds to the number of heat pump units operating in ON mode.

[0032] In an example, the master unit is configured to derive the operative number and to turn on said one or more heat pump units responsive to a plurality of intervals of hot water demand. In an example, a predetermined operative number is associated with each interval, so that in each interval of hot water demand a predetermined number of heat pump units work in the ON mode.

[0033] This solution allows having a water heating system that is more reliable and more efficient, capable of providing the hot water required.

[0034] In an example, the predetermined operative number of each interval is selectable by a user.

[0035] In an example, the master unit is configured to detect faulty heat pump units. In the case where the number of faulty units exceeds the derived operative number, the master unit is configured to turn on all the remaining heat pump units.

[0036] This solution allows improving the reliability and efficiency of the system.

[0037] It is therefore possible to enhance the reliability and efficiency of the system.

[0038] It should be noted that this disclosure provides an example in which the master unit is configured to turn on all the units which are not faulty in the case where the number of faulty units exceeds the derived operative number, and where the units are turned sequentially based on their ranking codes or on other criteria.

[0039] In an example, if the connection between the master and the slave units fails, the master unit is configured to continue working in a predetermined mode as a standalone heat pump unit with activated solenoid valve. Moreover, if the connection between the master and the slave units fails, the slave units which are not faulty continue working according to a predetermined setting. In particular, each heat pump unit has the set parameters which determine the function of the unit in the event of its failing to communicate with the master unit.

[0040] Each heat pump unit may have different modes. The modes of the heat pump units may include ON, OFF and STANDBY. In an example, in the standby mode, the water is heated by external heat sources such as, for example, thermal or photovoltaic solar panels. In an example, in the ON mode, the water is heated using power delivered directly by the heat pump.

[0041] According to an aspect of it, this disclosure provides a method for heating water. The method comprises a step of providing a water heating system. The water heating system comprises a plurality of heat pump units. Each heat pump unit (or unit for short) includes a water tank. Each heat pump unit is operable in an ON mode and in an OFF mode. In the ON mode, the heat pump is active to heat the water in the tank. In the OFF mode, the heat pump is inactive.

[0042] Each unit includes a water inlet. Each unit includes a water outlet. The water outlets of the heat pump units are in communication with each other to form a main water outlet.

[0043] Each unit includes a solenoid valve. The solenoid valve is located at the water outlet or inlet.

[0044] Each unit includes a temperature sensor. The temperature sensor is configured to detect the temperature of the water inside the water tank. Each unit includes a control unit. In each unit, the control unit is connected to the solenoid valve and to the temperature sensor.

[0045] The water heating system also comprises a bus. The control units are interconnected through the bus to exchange data.

[0046] The method comprises a step of running one of the heat pump units as a master unit and the remaining units as slave units.

[0047] The method comprises a step of deriving an operative number. The operative number is derived in response to a hot water demand. The operative number is the number of heat pump units working in ON mode needed to satisfy the hot water demand.

[0048] The method comprises a step of turning on one or more heat pump units, through the master unit, based on the derived operative number.

[0049] The method comprises a step of activating the solenoid valve of one or more of the heat pump units, through the master unit, responsive to the hot water demand. In an example, the number of activated solenoid valves may correspond to the number of heat pump units operating in ON mode. In an example, the master unit receives data relating to the temperature of the water tank of each heat pump unit. In an example, the master unit activates the solenoid valves of the heat pump units with the highest detected water tank temperature.

[0050] In an example, the method comprises a step of connecting the heat pump units in parallel. The method may comprise a step of associating a ranking code with each heat pump unit, through the master unit.

[0051] In an example, the method comprises a step of turning on the heat pump units, sequentially, based on the ranking code of each unit, for a predetermined time interval.

[0052] Furthermore, at the end of the predetermined interval, the ranking code of each unit is assigned to the adjacent one, through the master unit.

[0053] In an example, the heat pump units are turned on based on the ranking code of each unit and starting from the smallest ranking code.

[0054] In an example, the method comprises a step of turning ON said one or more heat pump units, through the master unit, responsive to a plurality of intervals of hot water demand, where a predetermined operative number is associated with each interval, so that in each interval of hot water demand, a predetermined number of heat pump units work in the ON mode.

[0055] These and other features will become more apparent from the following description of a preferred embodiment, illustrated purely by way of nonlimiting example in the accompanying drawings, in which:

- Figure 1 illustrates a water heating system according to this disclosure;
- Figure 2 illustrates the system with the units in the ON and OFF modes;
- Figures 3A and 3B illustrate the system in two different intervals;
- Figure 4 illustrates a heat pump of each unit of the system;
- Figure 5 illustrates the water heating system in combination with a thermal solar system.

[0056] With reference to the accompanying drawings, the numeral 1 denotes a water heating system. The water heating system 1 (or the system, for short) includes a plurality of heat pump units 2. Each heat pump unit 2 (or the unit, for short) includes a heat pump 100. The heat pump 100 includes a compressor 101. The compressor 101 has an inlet. The compressor also includes an outlet. The compressor 101 is configured to increase the pressure of a refrigerant.

[0057] The heat pump 100 also includes an evaporator 102. The evaporator has an inlet. The inlet of the evaporator 102 receives the refrigerant in the liquid state.

The evaporator 102 also includes an outlet. The evaporator outlet is used to release the refrigerant in the gaseous state. The evaporator receives a heat flow in a space adjacent thereto. The evaporator receives the heat flow from a fluid.

[0058] The heat pump 100 also includes an expansion valve 103. The expansion valve 103 is used to expand the refrigerant.

[0059] The heat pump includes a condenser 104. The condenser receives the refrigerant in the gaseous state. The condenser releases the liquid refrigerant at a low temperature. Each unit includes a water tank T.

[0060] The condenser 104 is located inside or outside the water tank T. The water tank of each unit 2 contains water to be heated by heat exchange with the condenser 104. Each heat pump unit works in an ON mode, in which the heat pump 100 is active to heat the water in the tank T, and an OFF mode, in which the heat pump 100 is inactive. Furthermore, each unit can also work in a STANDBY mode, in which the water is heated by external heat sources such as, for example, thermal or photovoltaic solar panels. Each unit includes a water inlet I and a water outlet O. The water inlet is connected to the water tank T and receives the water to be heated. The water outlets of the heat pump units are in communication with each other to form a main water outlet MO. Each unit also includes a solenoid valve V connected to the water outlet or inlet. In each unit, the temperature of the water inside the tank T is detected by a temperature sensor S. Each unit includes a control unit C. The control unit is connected to the solenoid valve V and to the temperature sensor S. The control units C of the plurality of heat pump units 2 are connected to each other through a bus so as to exchange data. One of the control units is programmed to work as a master control unit and controls the other control units, which work as slave control units.

[0061] Therefore, the unit with the master control unit works as master unit 2A and the units with the slave control units work as slave units 2B. The master unit derives an operative number responsive to a hot water demand and turns on one or more heat pump units 2 based on the derived operative number. The operative number is the required number of heat pump units which need to work in ON mode to satisfy the hot water demand. The master unit 2A activates the solenoid valve of one or more of the heat pump units. The number of activated solenoid valves may correspond to the number of heat pump units operating in ON mode. In particular, the master unit may derive the operative number responsive to a plurality of water demand intervals. For example, the plurality of water demand intervals may include a minimum level, an intermediate level and a maximum level. The master unit derives the operative number for each of these levels. In an example, a predetermined operative number is associated with each interval. Therefore, in each hot water demand interval, a predetermined number of heat pump units must work in the ON mode. For example, the system may have a database in which the operative number is saved for each hot water level (that is, the level of hot water demand) which is entered in the system. The operative number may be selected by a user and can be modified. Therefore, when the hot water demand level is entered in the master unit, the master control unit selects the predetermined operative number of that level and turns on the units 2 based on the selected operative number.

[0062] The master unit receives the temperature of the water tank, detected by the sensor S, of each heat pump unit and activates the solenoid valve V of the heat pump units with the highest detected temperature. Therefore, the valves which are active may be the valves not only of the units 2 which are switched on but also those of the units which are switched off. For example, if the plurality of units includes three units and the operative number entered for the hot water demand is two, the master unit turns on two heat pump units 2; in addition, the master unit 2A checks the temperature of the water in all the units (including itself) and opens the solenoid valves of the units with the highest temperature. Figure 2 shows an example in which the units which are switched on include the master unit and one slave unit but only the valves of the slave units are open, since the temperature of the master unit (45°C) is lower than that of the slave unit which is switched off (52°C). Thus, before opening the solenoid valves, the master checks all the units to identify which valves must be opened. The heat pump units 2 may be connected in parallel. The master unit 2A associates a ranking code with each heat pump unit, including itself, and turns on the units sequentially for a predetermined time interval. At the end of the predetermined time interval, the master unit assigns the ranking code of each heat pump unit to the adjacent one. The ranking code determines the order in which the units are turned on. In particular, the ranking code determines the position of each heat pump unit in the ranking which determines the order in which the units are turned on. For example, as shown in Figure 3A (an example in which the operative number is two), the master unit 2A and the slave unit 2B adjacent to the master unit, with the ranking codes 1 and 2, respectively, are switched on and working in the ON mode. When the predetermined time interval comes to an end, each unit receives the ranking code of the unit preceding it, and as shown in Figure 3B, the master unit switches off and the two slave units 2 work in ON mode.

[0063] The heat pump units each possess a serial code. The serial code is unique for each heat pump unit. Moreover, the serial code is always the same for each heat pump unit. In an example, the master unit is programmed to detect the serial code of each heat pump. The master unit uses the serial code as an identification code. In an example, for each heat pump unit, the serial code and the corresponding ranking code are stored in a database. The serial codes and the corresponding ranking codes may be stored in a memory of the control unit of the master unit. The serial codes and the corresponding ranking codes stored in the database determine the

sequence according to which the heat pump units are turned on by the master unit. Furthermore, the ranking codes associated with the serial codes may be modified dynamically as a function of one or more predetermined criteria. The predetermined criteria may be, for example: the number of hours or days of operation, or the number of times each heat pump unit has been switched on.

[0064] Therefore, the serial code of each heat pump unit may be associated with a ranking code and this data is stored in the database. This data stored in the database is subsequently used by the control unit of the master unit and the heat pump units are turned on sequentially and according to the ranking code stored in the database. At the end of every interval, the database is updated and the ranking code of each heat pump unit is changed. For example, at the end of the predetermined time interval, each heat pump unit receives the ranking code of the adjacent unit. In an example, the ranking codes are assigned to all the heat pump units, including the master unit.

[0065] In the event of one (or more) faulty units 2, the master unit 2A detects it and assigns its ranking code to the unit adjacent to the faulty unit. If the number of faulty units exceeds the derived operative number, the master unit turns on all the remaining heat pump units. If the connection between the master unit 2A and the slave units 2B fails, the master unit continues to work in the ON mode as a standalone heat pump unit and the solenoid valve V of the master unit remains open.

[0066] Moreover, if the connection between the master and the slave units fails, the slave units which are not faulty continue working according to a predetermined setting. In particular, each heat pump unit has the set parameters which determine the function of the unit in the event of its failing to communicate with the master unit.

[0067] Each heat pump unit may have different modes. The modes of the heat pump units may include ON, OFF and STANDBY. In an example, in the standby mode, the water is heated by external heat sources such as, for example, thermal or photovoltaic solar panels. In an example, in the ON mode, the water is heated using power delivered directly by the heat pump. When there is no communication with the master unit, each (non-faulty) unit continues to work in one of the modes determined for that unit in the event of a failed connection. For example, a slave unit may be configured to continue working in standby mode if it loses its connection with the master unit.

[0068] In particular, if the master unit 2A interrupts the connection between it and a slave unit 2B, the master unit is configured to identify the unit whose connection it has lost as a faulty unit and to exclude it from the heating system. In this case, a code identifying the fault appears on the display of the master unit.

[0069] The master unit is also configured to cyclically retry communicating with the slave unit identified as faulty in order to check whether the connection has been re-established. In this case, the slave unit is re-included in the control logic of the heating system.

[0070] If the slave unit 2B interrupts the connection between it and the master unit 2A, the slave unit, after a predetermined time interval, continues to work as a standalone heat pump unit in a predefined mode.

[0071] In this case, a code identifying the fault appears on the display of the slave unit.

[0072] Furthermore, if communication with the master unit is re-established, the slave unit returns to being controlled by the master unit.

[0073] In the event of a fault in any unit (whether master or slave), if the fault is such as to prevent its operation, that unit is identified as faulty and the master unit excludes it from the control logic of the heating system.

[0074] It should be noted that even when the master unit is affected by a fault which prevents it from operating but which nevertheless allows cascade control (controlling the plurality of interconnected heat pump units), the master unit is identified as faulty and excluded from the heating system (and used only to control the other units).

[0075] In this case, a code identifying the fault appears on the displays of both the master unit and the slave unit.

[0076] In particular, a code identifying the fault is displayed on the unit affected by the fault.

[0077] In an example, each of the heat pump units is configured to perform a plurality of auxiliary functions. In particular, even when the heat pump unit is configuration to be integrated in the water heating system according to this disclosure (water heater cascade heating system), it may control these auxiliary functions, independently of the configuration of the other units. The term "water heater cascade heating system" is used to mean a water heating system having a plurality of interconnected heat pump units in which one or more slave units are controlled by a master unit. Th plurality of auxiliary functions includes at least one of the following functions:

- Antifreeze function
- Antilegionella function
- Thermal solar function
- EVU function
- Photovoltaic function
- Smart-grid function

[0078] In the case of the antifreeze function, each unit is configured to continue controlling this function as if it were working as a standalone unit independent of the cascade heating system.

[0079] As regards the antilegionella function, when this function is enabled and the unit is programmed to work in cascade (according to this disclosure), irrespective of whether it is configured as a slave unit or as the master unit, the antilegionella function is always activated after a predetermined time delay, as occurs when the unit is working as a standalone unit. Even if the temperature of the water in the tank T reaches a certain setpoint for legionella disinfection during this time delay, the antilegionella function is not activated until the time delay has

elapsed.

[0080] Moreover, to prevent this function from being enabled simultaneously on two or more units, leading to excessive consumption, at each power-on, each unit initializes its own counter which counts the days which have passed between one antilegionella cycle and another and based on its own ranking code.

[0081] As regards the thermal solar function, a thermal solar system may be provided for use in combination with the cascade function according to this disclosure.

[0082] In particular, Figure 5 illustrates the water heating system 1 according to this disclosure, combined with a thermal solar system.

[0083] The thermal solar system includes a solar panel 3 and a temperature probe 4. In particular, the probe 4 is connected to the motherboard of the master unit 2A.

[0084] The thermal solar system also includes a solar pump 5 which must be connected to the control unit of the master unit 2A. The electric power supply of the solar pump 5 must be regulated by solar safety thermostats 6 (one for each unit) which must be connected in series. This solution allows stopping the solar pump in the event of overheating of one of the heat pump units.

[0085] In particular, to avoid both installation complexity and excessive cost of components, the cascade function of the heating system is capable of monitoring the temperature of the thermal solar panels 3 through the temperature probe 4 (one probe only) and controlling the circulation of the water between solar panels and a solar coil 105 of the unit (each unit) through the pump 5 (one pump only). The probe and the pump are physically connected to the master unit which controls their operation. The master unit transmits the temperature of the probe 4 to the slave units and controls the circulation pump, even if only one unit of the plurality of units requires its use with a solar panel, thus allowing each unit to control this function as if it were working as a standalone unit (independent of other units).

[0086] As regards the EVU function, like the thermal solar function, to avoid both installation complexity and excessive cost of components, if electrical energy is provided under a reduced rate contract and it is to be used in combination with the cascade function, the cascade function is capable of controlling the device supplied by the energy provider by connecting the provider's device only to the unit configured as master unit.

[0087] In particular, the master unit is configured to transmit to the slave units the state of the digital input assigned to the EVU function, thus allowing each unit to control this function as if the unit were working as a standalone unit. As regards the photovoltaic function, to avoid both installation complexity and excessive cost of components, a photovoltaic system may be provided for use in combination with the cascade function. In this case, the cascade function is capable of controlling the state of the system using only the digital input of the unit configured as master unit.

[0088] The master unit transmits to the slave units the state of the digital input assigned to the photovoltaic function, thus allowing each unit to control this function as if the unit were working as a standalone unit.

[0089] As regards the smart grid function, a SMART GRID function may be used in combination with the cascade function. In such an example, the cascade function is capable of controlling the different states of the SMART GRID using only the digital inputs of the unit configured as master unit.

[0090] In this case, the master unit transmits to the slave units the current state of the SMART GRID, thus allowing each unit to control this function as if the unit were working as a standalone unit.

[0091] It should be noted that if a slave unit 2B interrupts the connection between it and the master unit 2A, as explained above, the slave unit, after the predetermined time interval, continues to work as a standalone heat pump unit in a predefined mode and the auxiliary, thermal solar, EVU, photovoltaic and Smart Grid functions are disabled because the master unit would no longer be able to receive the reading of the solar panel probe and the state of the digital inputs.

Claims

1. A water heating system (1), comprising a plurality of heat pump units (2), wherein each heat pump unit includes:

- a water tank (T), wherein the heat pump unit is operable in an ON mode, wherein the heat pump is active to heat the water in the tank (T), and an OFF mode, wherein the heat pump is inactive;
- a water inlet (I) and a water outlet (O), wherein the water outlets of the heat pump units communicate with each other to form a main water outlet (MO);
- a solenoid valve (V) at the water outlet (O) or the water inlet (I);
- a temperature sensor (S), for detecting the temperature of the water inside the water tank;
- a control unit (C), connected to the solenoid valve (V) and to the temperature sensor,

the water heating system further comprising a bus, wherein the control units are interconnected through the bus to exchange data, and being **characterized in that** the control units are programmed so that one of the heat pump units (2) acts as a master unit (2A) and the remaining units act as slave units (2B),

wherein the master unit is programmed to derive an operative number responsive to a hot water demand, the operative number being the required number of heat pump units working in ON mode to satisfy the

hot water demand, and wherein the master unit is programmed to turn on one or more heat pump units (2) based on the derived operative number, the master unit being further programmed to activate the solenoid valve of one or more of the heat pump units, responsive to the hot water demand.

2. The water heating system (1) according to claim 1, wherein the master unit is configured to receive data relative to the water tank temperature of each heat pump unit and to activate the solenoid valve (V) of the heat pump units with the highest detected water tank temperature.

3. The water heating system (1) according to claim 2, wherein the heat pump units (2) are connected in parallel, and the master unit (2A) is programmed to associate a ranking code with each heat pump unit, the master unit being further programmed to turn on the heat pump units, sequentially, based on the ranking code of each unit, for a predetermined time interval, wherein at the end of the predetermined time interval, the master unit is configured to assign the ranking code of each heat pump unit to the adjacent one.

4. The water heating system (1) according to claim 3, wherein the master unit is configured to detect faulty heat pump units and to assign the ranking code of each faulty unit to the adjacent unit.

5. The water heating system (1) according to any of the previous claims, wherein the number of activated solenoid valves corresponds to the number of heat pump units operating in ON mode.

6. The water heating system (1) according to any of the previous claims, wherein the master unit is configured to derive the operative number and to turn on said one or more heat pump units responsive to a plurality of intervals of hot water demand, wherein a predetermined operative number is associated with each interval, so that in each interval of hot water demand a predetermined number of heat pump units work in the ON mode.

7. The water heating system (1) according to claim 6, wherein the predetermined operative number of each interval is selectable by a user.

8. The water heating system (1) according to any of the previous claims, wherein the master unit is configured to detect faulty heat pump units and, if the number of faulty units exceeds the derived operative number, the master unit is configured to turn on all remaining heat pump units.

9. The water heating system (1) according any of the previous claims, wherein, if the connection between the master and the slave units fails, the master unit is configured to continue working in the ON mode as a standalone heat pump unit with activated solenoid valve.

10. A method for heating water comprising the following steps:

- providing a water heating system (1) comprising a plurality of heat pump units (2), wherein each heat pump unit includes:

  a water tank (T), wherein the heat pump unit is operable in an ON mode, wherein the heat pump is active to heat the water in the tank, and an OFF mode, wherein the heat pump is inactive;
  a water inlet (I) and a water outlet (O), wherein the water outlets of the heat pump units communicate with each other to form a main water outlet (MO);
  a solenoid valve at the water outlet (O) or at the water inlet (I);
  a temperature sensor (S), for detecting the temperature of the water inside the water tank;
  a control unit (C), connected to the solenoid valve and to the temperature sensor,

wherein, the water heating system further comprises a bus, wherein the control units are interconnected through the bus to exchange data, **characterized in that** the method further comprises the following steps:
- running one of the heat pump units (2) as a master unit (2A) and the remaining units as slave units (2B),
- deriving an operative number responsive to a hot water demand, the operative number being the required number of heat pump units working in ON mode needed to satisfy the hot water demand,
- turning on one or more heat pump units (2), through the master unit, based on the derived operative number,
- activating the solenoid valve of one or more of the heat pump units, through the master unit, responsive to the hot water demand.

11. The method according to claim 10, wherein the master unit receives data relative to water tank temperature of each heat pump unit and activates the solenoid valve of the heat pump units with the highest detected water tank temperature.

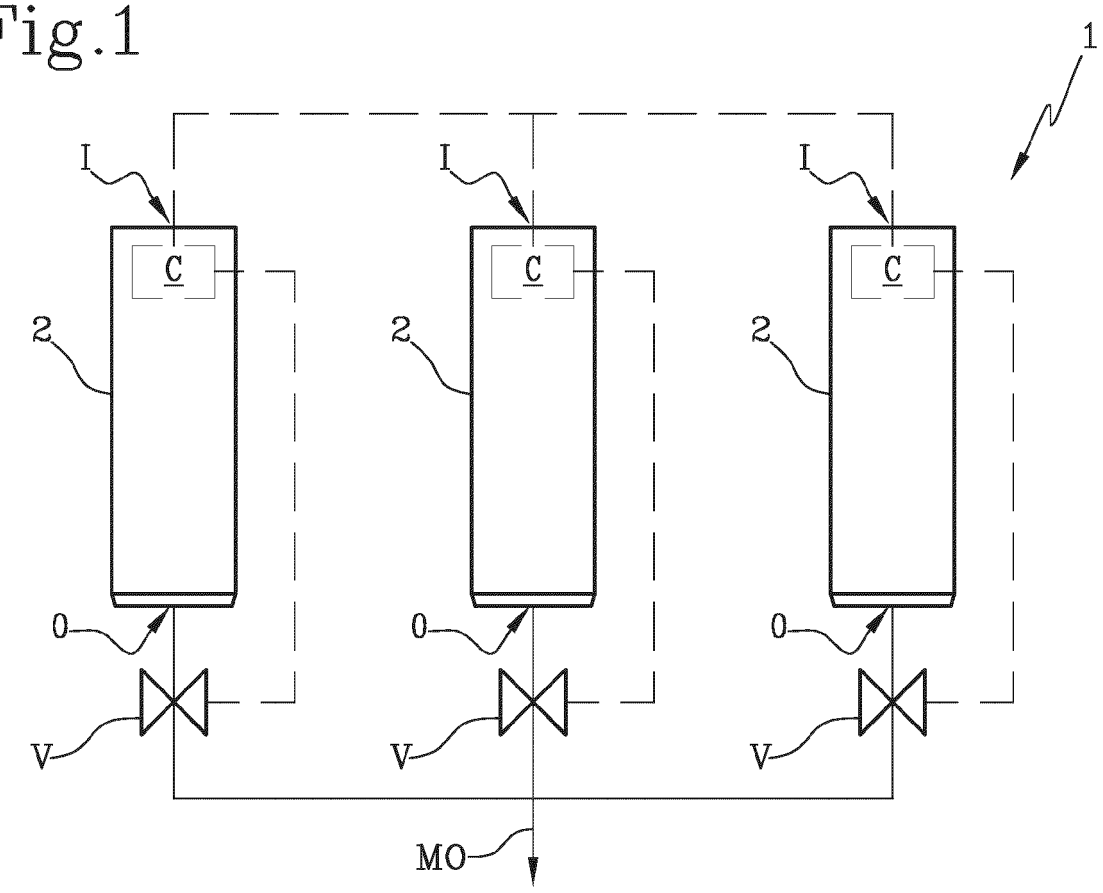
12. The method according to claim 10 or 11, comprising

the following steps:

- connecting the heat pump units in parallel;
- associating a ranking code with each heat pump unit, through the master unit;
- turning on the heat pump units, sequentially, based on the ranking code of each unit, for a predetermined time interval,
- at the end of the predetermined interval, assigning the ranking code of each heat pump unit to the adjacent one, through the master unit.

13. The method according to any of the previous claims from 10 to 12, comprising a step of turning ON said one or more heat pump units, through the master unit, responsive to a plurality of intervals of hot water demand, wherein a predetermined operative number is associated with each interval, so that in each interval of hot water demand a predetermined number of heat pump units work in the ON mode.

Fig.1



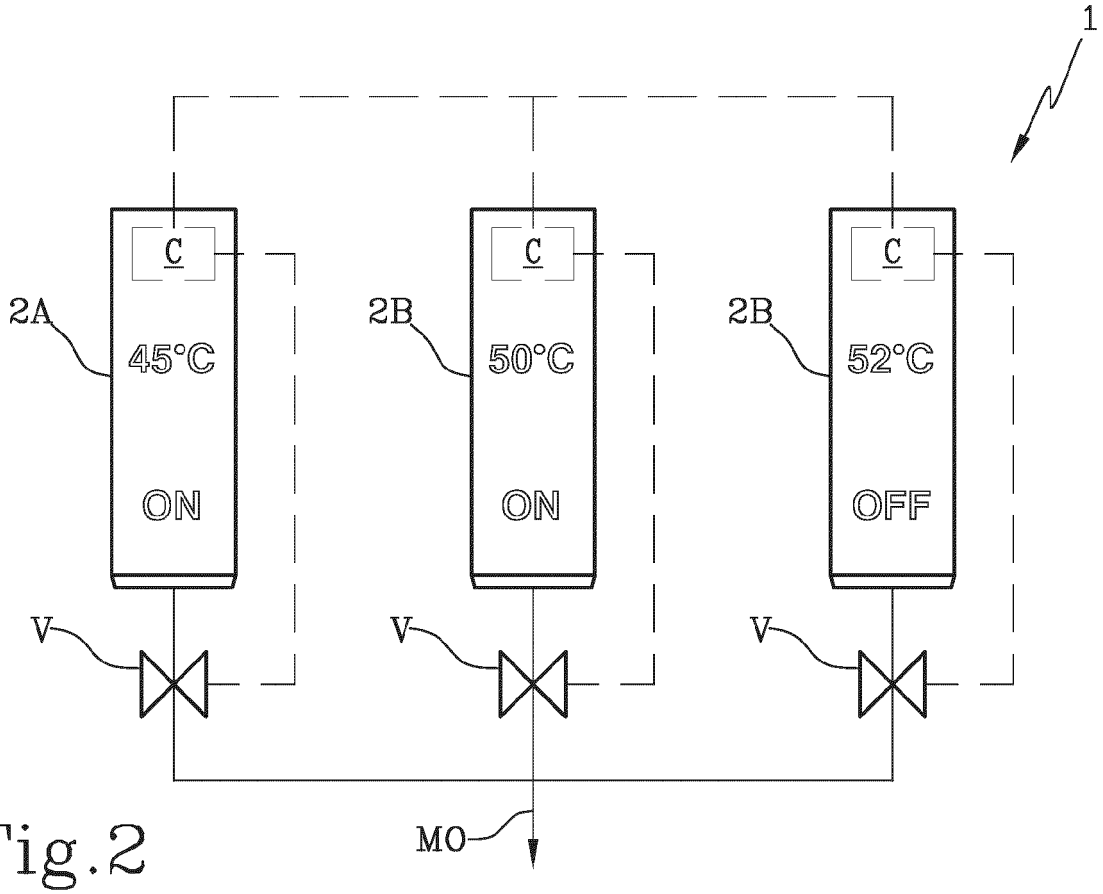
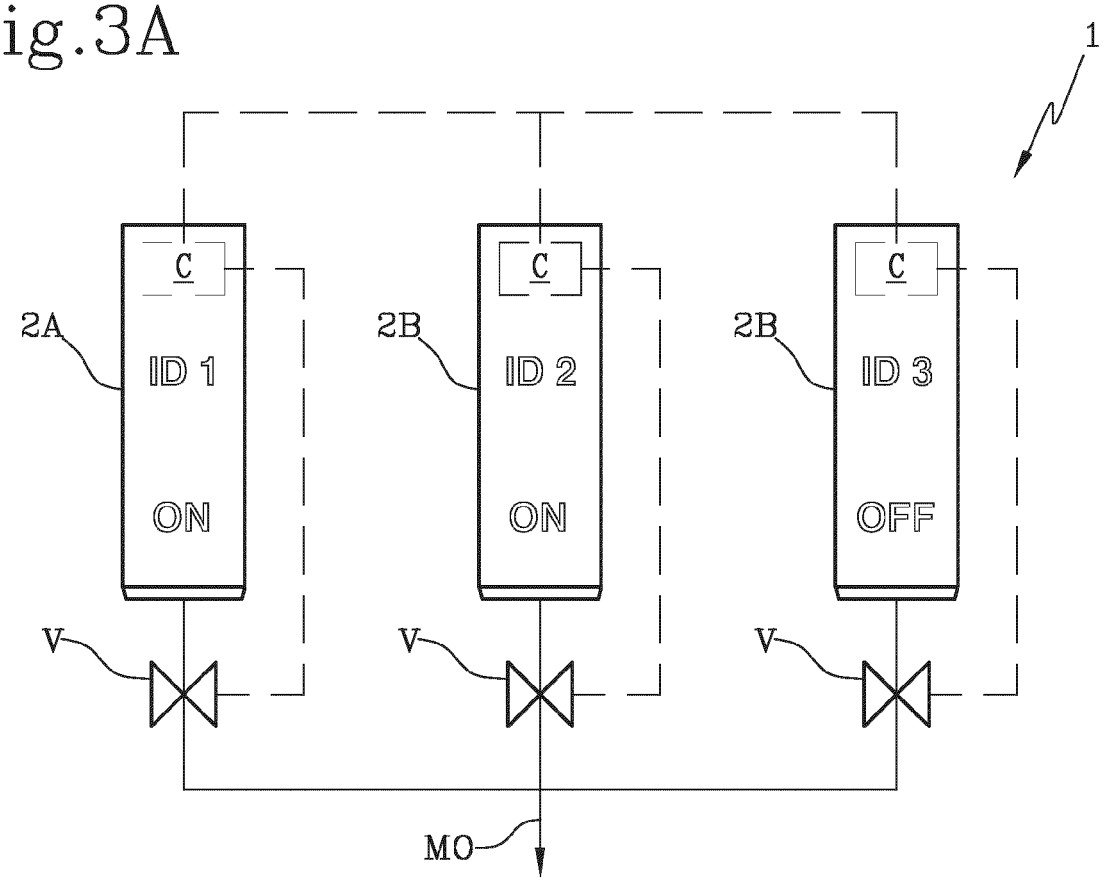


Fig.2

Fig.3A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C
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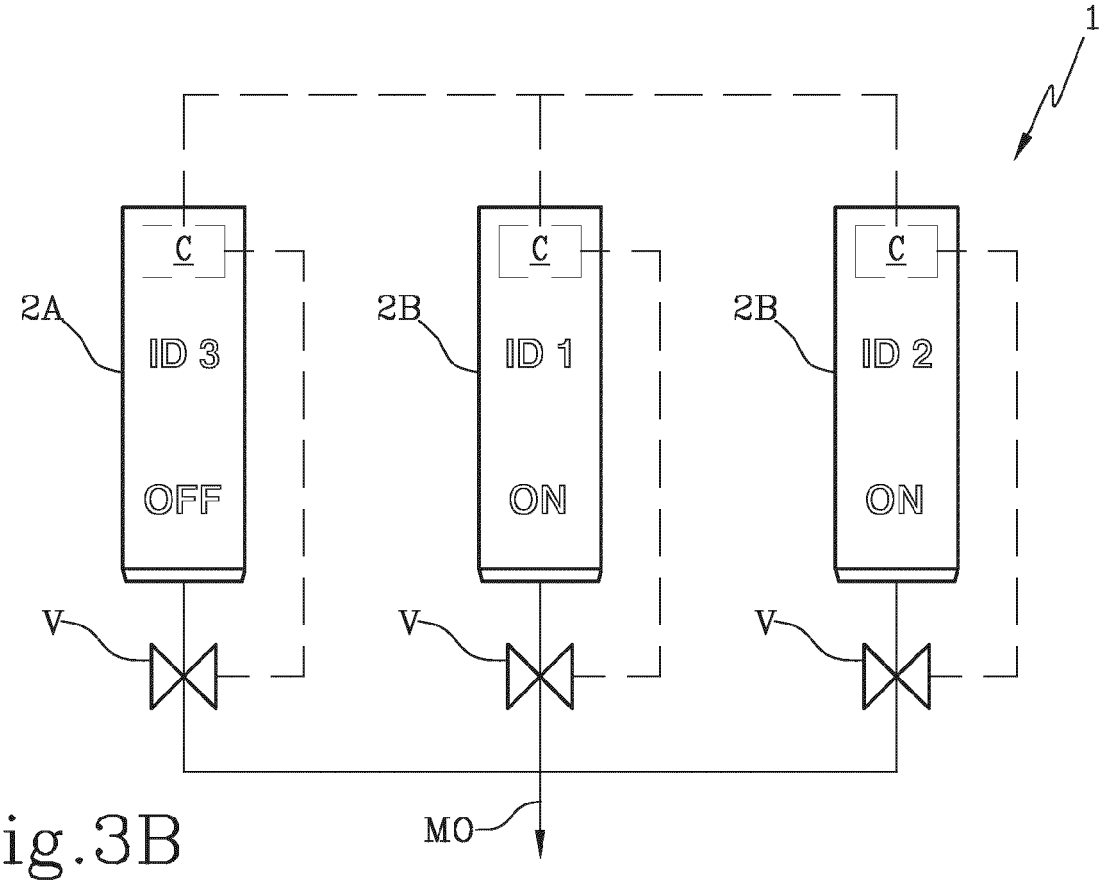
ID 1
ON
V
C
2B
ID 2
ON
V
C
2B
ID 3
OFF
V
MO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MO

Fig.3B

Fig.4

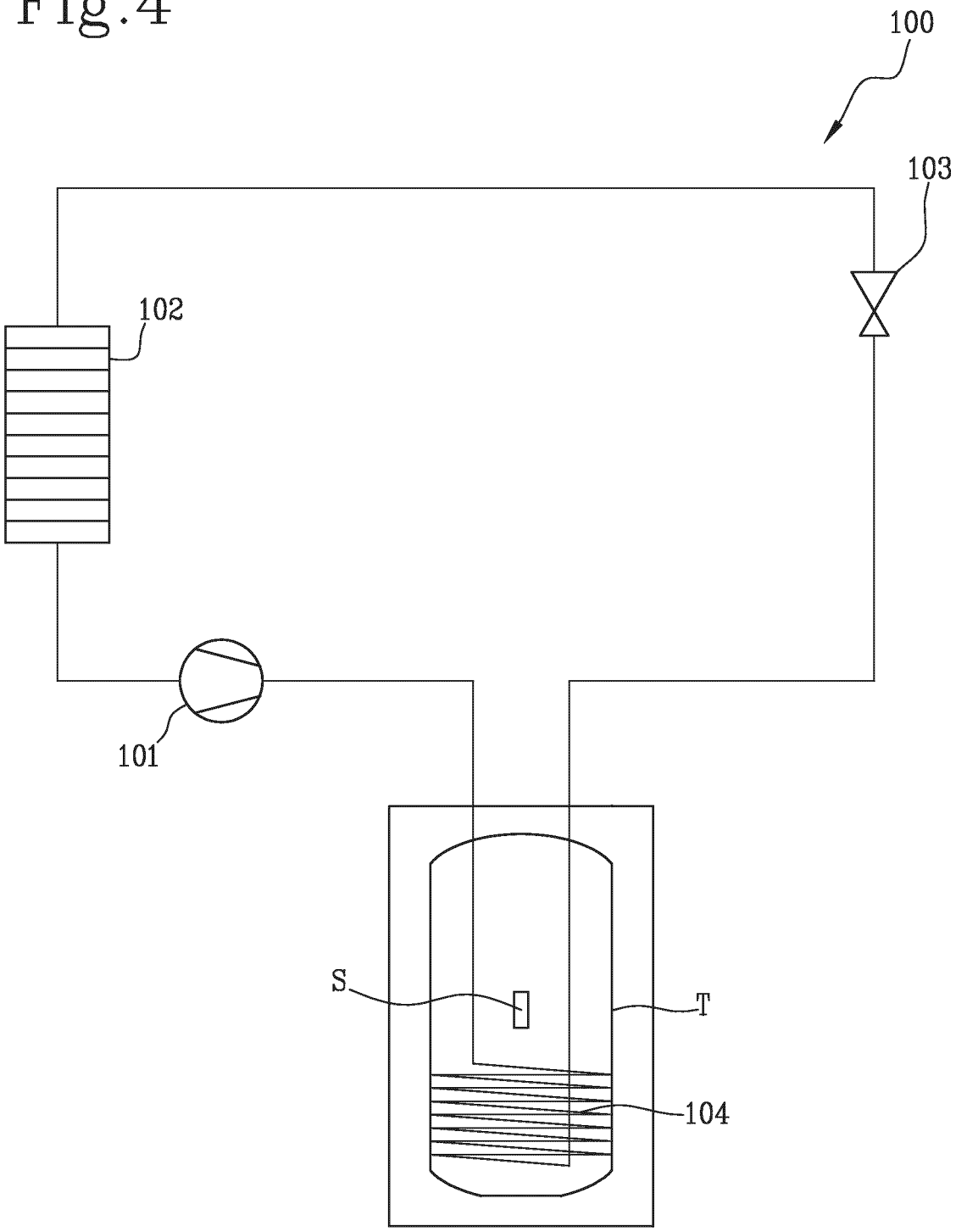
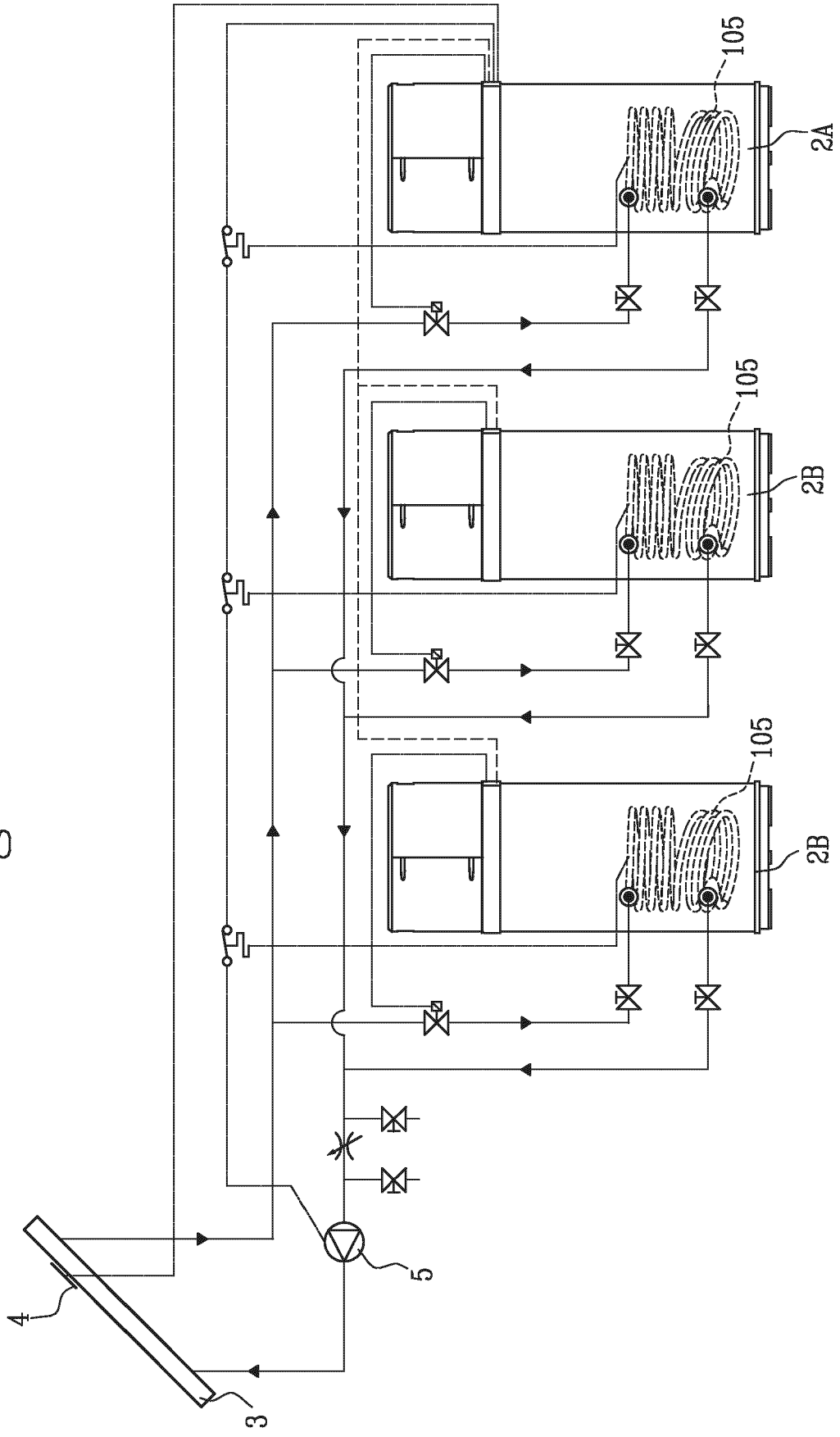


Fig.5



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EUROPEAN SEARCH REPORT

Application Number
EP 24 19 2501

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A	CN 107 062 589 A (GUANGZHOU DINGFU ELECTRONIC TECH CO LTD) 18 August 2017 (2017-08-18) * paragraphs [0016], [0025] - [0028], [0038] - [0056]; figure 1 *	1-13	INV. F24H4/04 F24H9/20 F24H15/104 F24H15/223 F24H15/269 F24H15/281 F24H15/31 F24H15/375 F24H15/429 F24H15/436 F24H15/443
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F24D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	25 November 2024	Schwaiger, Bernd

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