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(54) Titre : PROCÉDÉ DE RÉGULATION D'UNE INSTALLATION COMPRENANT DES APPAREILS DE COGÉNERATION ET DES SYSTÈMES THERMODYNAMIQUES DESTINÉS A LA CLIMATISATION ET/OU AU CHAUFFAGE

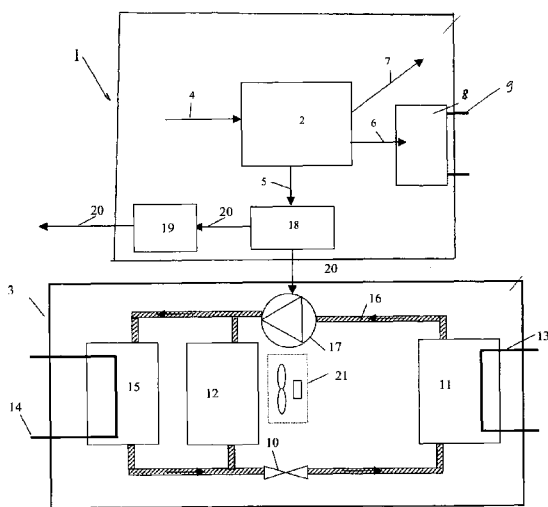


Figure 1

(57) Abstract : Method of managing a plant comprising cogenerating installations and thermodynamic systems, and a computing machine, said method comprising the following steps: a) "base data" are entered into the computing machine, comprising at least the resilience to electrical impact of the cogenerating installation, and the value of maximum intensity of the heat pump, b) "instantaneous data" are entered into said computing machine, comprising at least the state of the cogenerating installation, the state of the heat pump and the electrical power demanded by the heat pump, c) "target data" are defined, to which are assigned a respective "target value" in said computing machine, these target data comprising at least the minimum and/or maximum production of electricity by the plant, optionally the maximum consumption of electricity and of primary energy, and at least one from among: the temperatures of very hot water (T2), of hot water (T1), of cold water (T3), of evaporation of coolant fluid (T4, T5), and the electricity demand of the local network, d) the plant is regulated with the aid of said computing machine in such a way as to attain, for each of the target data selected, the target value or values which have been assigned thereto, the regulation being performed by adjustment of at least one "adjustment datum", in such a way that the current value of each target datum selected is made to approach the target value assigned to it in step c), the at least one adjustment datum comprising the electrical power provided by the cogenerating installation.

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Procédé de gestion d'une installation comprenant des appareils de cogénération et des systèmes thermodynamiques, et une machine informatique, ledit procédé comprenant les étapes suivantes: a) On entre des «données de base» dans la machine informatique, comprenant au moins la tenue à l'impact électrique de l'appareil de cogénération, et la valeur d'intensité maximale de la pompe à chaleur, b) on entre des «données instantanées» dans ladite machine informatique, comprenant au moins l'état de l'appareil de cogénération, l'état de la pompe à chaleur et la puissance électrique demandée par la pompe à chaleur, c) on définit des «données cibles» à laquelle sont affectées une «valeur cible» respective dans ladite machine informatique, ces données cibles comprenant au moins la production minimale et/ou maximale d'électricité par l'installation, éventuellement la consommation maximale d'électricité et d'énergie primaire, et au moins une parmi: les températures d'eau très chaude (T2), d'eau chaude (T1), d'eau froide (T3), d'évaporation de fluide frigorigène (T4, T5), et la demande en électricité du réseau local, d) on régule l'installation à l'aide de ladite machine informatique de manière à atteindre, pour chacune des données cibles sélectionnées, la ou les valeurs cibles qui leur ont été affectées, la régulation l'ajustement d'au moins une «donnée d'ajustement», de manière à rapprocher la valeur actuelle de chaque donnée cible sélectionnée de la valeur cible qui lui a été affectée à l'étape c), la au moins une donnée d'ajustement comprenant la puissance électrique fournie par l'appareil de cogénération.

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**METHOD OF REGULATING AN INSTALLATION COMPRISING
COGENERATING MACHINES AND THERMODYNAMIC SYSTEMS
INTENDED FOR AIR CONDITIONING AND/OR HEATING**

5 The invention relates to a method of regulating an installation associating one (or several) cogeneration machines and one or several thermodynamic systems intended for air conditioning and/or heating. These thermodynamic systems are more commonly referred to as: air conditioner (whether or not reversible), water cooler or heat pump (whether or not reversible).

10 There exists on the market so-called cogeneration machines that simultaneously produce electrical energy and heat. These cogeneration machines deliver, generally over an associated electrical network, a given electrical power. This electrical power is the main desired value to be respected by the machine when it is operating. The associated electrical network is most often a low-voltage network. When it is associated with a network of this type, the cogeneration machine operates in synchronized mode at 50 Hz (in Europe) or 60 Hz
15 ("Synchrocoupling").

The peaks in electricity demand that are higher than the power that the machine is able to provide are absorbed by the associated electrical network. The thermal energy delivered by the cogeneration machine when it is
5 operating depends on the desired electrical power. This thermal energy is sent to a heating network by the intermediary of a heat transfer fluid. When the thermal energy produced is greater than the heat requirement, the excess is evacuated by an external device (for example
10 air coolers). When the thermal energy produced is less than the thermal requirement, a supplement is provided by another external device (for example a boiler). The generators of these cogeneration machines are usually conventional thermal engines (4-stroke mono- or multi-
15 cylinder) connected to an alternator. Moreover, other types of generators are starting to appear such as for example fuel cells.

There exists on the other hand on the air conditioner market, water coolers and heat pumps (whether
20 or not reversible) based on the thermodynamic cycle of cooling/heating by mechanical compression. The immense majority of these products use electrical energy (usually coming from the low-voltage network). This electrical energy is used by an engine & compressor unit often
25 combined into a piece of equipment then called moto-compressor which transfers by the intermediary of a coolant fluid the heat from a source (for example the outside air, the heat coming from a geothermal probe or from a water table) to a load (for example the water of a
30 heating circuit or domestic hot water). The thermal power transmitted to the source is the main desired value that the heat pump has to respect. The electrical power

consumed by the heat pump is induced by this requirement of thermal power. The liaison is not entirely direct because phenomena such as the size of the compressor, the value of the inrush current, the operating conditions
5 affect the instantaneous power demanded. The power available on the electrical network is rarely a problem as the electricity is produced by large-size plants (typically a gas turbine or nuclear plant), with centralized and permanent management of the energy.

10 Finally there exists installations that associate a cogeneration machine and a heat pump, such as is described for example in patent FR 2 927 161 and patent application WO 2011/01573 in the name of the applicant. In the devices of these documents, the cogeneration
15 machine is more preferably not connected to the network, but can be connected to it optionally.

More precisely, patent FR 2 927 161 describes a multi-energy thermodynamic device for the simultaneous production of hot water, lukewarm water, cold water and
20 of electricity, and more particularly a system or device comprising a heat pump actuated by an AC generator which allows for the simultaneous production of electricity, of hot water for example for heating buildings, of very hot water, for example domestic hot water, and of cold water,
25 for example for air conditioning. The device described in this patent is an association of a cogeneration machine which is a combustion engine or a fuel cell, and a heat pump.

Patent application WO 2011/01573 relates to a system
30 or device of modular design comprising at least one electric current generator module and one or several modules from among the following types: heat pumps,

cooling or mixed heat pump/cooling modules, which allow for the simultaneous production of hot water for example for heating buildings, of very hot water, for example for domestic hot water, of cold water, for example for air conditioning, optionally coolant fluid typically for refrigeration and optionally for electricity.

In the installations described by the documents hereinabove, the desired value or values to be respected are desired thermal values, with the electricity being produced, in quality and in quantity, in a suitable manner to provide for the requirements of the compressor or compressors of the heat pump or pumps so that they transfer the required energy to the coolant fluid. The installation is managed by a control apparatus ("supervisor") whether integrated or not into the installation comprising a hardware portion "commonly referred to as "hardware") and an algorithm portion (commonly referred to as "software"),

The association of a cogeneration machine and of a heat pump is interesting as this makes it possible to share the thermal energies produced by each machine and this also makes it possible where applicable a "multi-energy" approach: electricity + fuel (natural gas or other: biogas, diesel, hydrogen, etc.). However the optimized implementation of these two technologies on the same application, on the same site, requires a method of management that can take into account the constraints linked to each machine, and as such allow for a global economic optimization of the system by measuring the energy consumption and production (thermal and electrical) by associating according to the rates in effect the opportunity of a strictly economic choice or linked to

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constraints with the source of energy available (type, for example natural gas and biogas and quantity).

It is desirable that embodiments of the invention provide a method of regulating an installation comprising one (or several) cogeneration machines and one or several thermodynamic systems (for example a heat pump) heat pump (and/or a refrigeration machine: air conditioner or water cooler).

It is desirable that embodiments of the invention provide a method of regulating an installation comprising a cogeneration machine and a heat pump (and/or a refrigeration machine), said cogeneration machine and heat pump not comprising sensors, hardware, or software allowing them to exchange information in order to operate between them in a suitable and optimized way.

It is desirable that embodiments of the invention allow for a simultaneous thermal and electrical optimization by taking into account the available energy sources and the costs of said sources.

According to the present invention, there is provided a method of managing an installation comprising one or several cogeneration machines and one or several thermodynamic systems, such as heat pumps, as well as a computing machine, said method comprising the following steps:

(a) Data called "base data" are entered into said computing machine, with said base data comprising at least the resilience to the electrical impact of the cogeneration machine, the value of maximum intensity of the heat pump,

(b) Data called «instantaneous data» are entered into said computing machine, with said instantaneous data comprising at least the state of the cogenerating machine, the state of the heat pump and the electrical power
5 demanded by the heat pump,

(c) Data called "target data" are defined to which are assigned a respective "target value" in said computing machine, said target data comprising at least the minimum and/or maximum production of electricity by
10 the installation, optionally the maximum consumption of electricity and of primary energy, and at least one from among: the temperatures of very hot water (T2), of hot water (T1), of cold water (T3), of evaporation of coolant fluid (T4, T5), and the electricity demand of the local
15 network,

(d) the installation is regulated with the aid of said computing machine in such a way as to attain, for each piece of the target data selected, the target value or values which have been assigned thereto, with the
20 regulation being performed by comparing the current value of the target data selected, by taking into account the base data selected as well as the instantaneous data selected, and by adjusting at least one piece of "adjustment data", in such a way that the current value
25 of each piece of target data selected is made to approach the target value assigned to it in step c), with the at least one piece of adjustment data comprising the electrical power provided by the cogeneration machine.

In other embodiments, at least one additional piece
30 of "base data" of step (a) is selected in the group formed by (da1) the unit cost of the fuel of each combustion engine (2), fuel cell and absorption heat pump

used in the system; (da2) the energy content of each fuel; (da3) CO₂ impact of each fuel by unit of mass; (da4) the energy efficiency of each combustion engine (2) according to its load and its speed of rotation, which makes it possible to determine the quantity of CO₂ released per unit of mechanical power produced by this combustion engine (2); (da5) the nominal power at full load of each combustion engine (2) according to its speed of rotation; (da6) the percentage of thermal power recovered on the cooling circuit of the combustion engine (2) and the percentage of thermal power recovered on the exhaust gases and/or the quantity of CO₂ released per unit of thermal power produced by the combustion engine (2), (da7) the unit cost of the electrical energy provided by the external network; (da8) the service life of each generator according to its load; (da9) the maintenance cost of each generator according to the number of hours of operation; (da10) the cost of disassembling and replacing each generator; (da11) the service life, the cost of maintenance, the cost of disassembling and replacing each type of heat pump; (da12) the efficiency of the alternator according to the electrical power that is provides, which makes it possible to determine the mechanical power demanded of the combustion engine (2) for an electrical power provided; (da13) the efficiency of the fuel cell according to its load; (da14) the efficiency of the inverter of the fuel cell or of the photovoltaic solar panels when they exist; (da15) the electrical consumption and the flow rate of the circulation pump of the solar collectors; (da16) the unit sales price of the electrical energy provided to the external network.

In other embodiments, at least one additional piece of "instantaneous data" is selected in the group formed by: (db1) the instantaneous electrical power produced by each current generator present; (db2) the rotation speed of each combustion engine (2); (db3) the instantaneous consumption in fuel of the installation (1); (db4) the temperature of the fluid recovering the thermal energy of the combustion engine (2); (db5) the instantaneous electrical power consumed by the installation (1) with the network, obtained through a direct measurement; (db6) the instantaneous power provided to the network by the installation (1), obtained through a direct measurement; (db7) the current, the voltage or the instantaneous electrical power produced by the photovoltaic solar panel (if this panel is present); (db8) the instantaneous temperature T1; (db9) the instantaneous temperature T2; (db10) the instantaneous temperature T3; (db11) the instantaneous temperature T4 (db12) the instantaneous temperature T5 (db13) the temperature of the ambient air; (db14) the number of hours of operation of each electric current generator (mainly combustion engine 2 and fuel cell; (db15) the number of hours of operation of each heat pump circuit of the installation (vapor compression or absorption type).

In other embodiments, at least one additional piece of "target data" is selected in the group formed by: (dc1) the temperature T1 and its change according to in particular the outside temperature; (dc2) the temperature T2 and its change according to in particular of the outside temperature; (dc3) the temperature T3 and its change according to in particular of the outside temperature; (dc4) the temperature T4 and its change

according in particular to the temperature desired in the refrigerated space; (dc5) the temperature T5 and its change according in particular to the temperature desired in the refrigerated space (dc6) the global COP as being the maximum global COP for the installation (1) or the minimum global CO2 impact of the installation (1); (dc7) the energy cost as being
5 the minimum energy cost of the installation (1); (dc8) the total operating cost as being the total minimum operating cost of the installation (1).

In other embodiments, at least one additional piece of "adjustment data" is selected in the group formed by: (dd1) the type, the number of current generators in operation, and the electrical power provided by each one of said generators; (dd2) the assigning of the electrical
10 power provided by the generator or generators respectively to the installation and to the network external to the installation (1); (dd3) the type and the number of heat pumps in operation; (dd4) in the case of vapor compression heat pumps, the volumetric flow rate adjustment (expressed as a percent) imposed by the regulation on the compressors in order to optimize the installation (1).

15 The "current" value of the at least one piece of target data selected is determined from time to time or regularly or continuously.

Said base data can be entered into the computing machine either when it is initially programmed, or when the installation is put into service, or by the user of the installation, over the course of time during the use of the installation.

20 In a particular embodiment, the method of regulating further comprises the steps of:

- Starting the cogeneration machine and starting the heat pump,

- Controlling (i.e. limiting to a maximum value) the electrical power demanded by the heat pump, more preferably via an analog or all-or-nothing signal, in such a way as to prevent the cogeneration machine from overloading.

- Commissioning and controlling pumps such as heating and air conditioning water pumps, domestic hot water pumps,

- Commissioning and controlling hydraulic two- and three-way valves,

- Rendering adequate, by using modeling and control algorithms, the electricity requirement of the heat pump and of the production of electricity by the cogeneration machine, in such a way as to respect the desired values (target values) for thermal powers (hot water for heating, domestic hot water, cold air conditioning water, etc.), and optionally the desired value (target value) of electricity demand on the local network, while still obtaining a minimum resulting consumption of primary energy and of electricity.

In an embodiment, the controlling of the electrical power demanded by the heat pump can be obtained by limiting the slope of the loading of the output of water to the customer (typically in degrees/minute), i.e. by limiting the speed of the increase in temperature of the water of the heating circuit.

Calculating the adequacy involves the use of various parameters, which include parameters from medium outside of the machines, such as the temperature of the outside air, the date and time (in order to take the peak/off-

peak rates into account for example), the limiting of the increase in temperature of the water, and parameters linked to the machines, such as information on the state of the pumps or of the valves. The results of the calculation produce the putting into service of various actuators (pumps, hydraulic valves).

5 In the framework of managing and optimizing the consumption of energy, the method of management manages the type of energy consumed by the installation, in particular electricity and fossil energy such as natural gas, and optionally also biogas or fuel, hydrogen, the electrical network coming from renewable energy, taking into account the quantity demanded and the cost of this energy. The choice of the types of energy can be automatic for
10 the purposes of a minimum instantaneous energy cost, or a minimum cost of possession that makes use of the cost of maintenance. This choice of the types of energy can also come from a calendar or from customer demand, or from the imposition locally or remotely from an intelligent network of the "Smart Grid" type.

15 Furthermore, in a particular embodiment, the method of management takes weather forecasts into account, in such a way as to manage the storage and the removal from storage of energy according to the requirements. This storage can take place in the walls of the building to which the installation is associated, or in a dedicated thermal storage, such as, in a non-restricted manner, a water storage tank.

The present invention will now be described, by way of non-limiting example only,
20 with reference to the accompanying drawings briefly described as follows.

Figures 1 and 2 refer to the installation regulated by the method.

Figure 1 shows a block diagram of the installation regulated by the method, in the case where the AC generator is a combustion engine connected to an alternator and the heat pump uses the vapor compression cooling cycle.

25 Figure 2 shows a block diagram of the installation regulated by the method, in the case where the AC generator is a combustion engine connected to an alternator and the heat pump uses the absorption cooling cycle.

List of markings

- 1 Installation regulated by the method
- 2 Combustion engine
- 5 3 Heat pump
- 4 Liquid or gaseous fuel inlet
- 5 Mechanical energy produced by the engine
- 6 Heat emitted by the AC generator in operation
- 7 Energy losses
- 10 8 Heat exchanger for exchanging heat between the AC generator and the very hot water
- 9 Very hot water circuit
- 10 Pressure regulator
- 15 11 Reversible heat exchanger - Condenser in heating mode, exchanger on the load in heating mode
- 12 Reversible heat exchanger - Evaporator in heating mode, exchanger on the source of heat in heating mode
- 13 Water circuit – cold water circuit when the heat pump is in air conditioning mode

- 14 Hot water circuit
15 Heat exchanger
16 Coolant fluid circuit
17 Compressor
5 18 Alternator
19 Electrical accumulator
20 Electrical energy
21 Motorized fan
24 DC/AC converter
10 27 Heat pump using the cycle by absorption
28 Absorber
29 Generator
30 Circulation pump
31 Evaporator of the absorption cycle
15 32 Pressure regulator adapted to the absorption
cycle
33 Condenser of the absorption cycle
34 Coolant fluid
35 Absorber

20

Definitions

In this document

- Thermodynamic system of the heat pump or cooling type: Device comprising a compressor and several
25 exchangers wherein a specific transfer fluid flows usually referred to as a coolant fluid, said device making it possible to absorb the thermal energy at a first temperature, and to restore thermal energy at a second temperature, with the second temperature being
30 higher than the first.
- Heat exchanger: Device intended to transfer heat between several circuits.

- Transfer fluid: Heat transfer fluid used to transfer heat; the conventional examples are coolant fluid, water or glycol water sometimes referred to as brine.

5 - Thermal source or source: by convention, the terms source and thermal load refer to the heating mode. The source is the medium from which the heat is extracted in heating mode. This extraction of heat takes place with certain physical characteristics such as thermal inertia
10 or the available power that characterize the source. It can be noted that the term source is improper in cooling mode since heat coming from the building is in fact released therein.

- Thermal load or load: the load is the medium where
15 the heat is released in heating mode. This heat rejection takes place with certain physical characteristics such as thermal inertia or the available power that characterize the load, likewise the load is the place where the heat is withdrawn in cooling mode.

20 - COP or coefficient of performance: the COP or coefficient of performance of a system in heating mode is defined as the ratio between the heating power available over the electrical power consumed by the system. In the system according to the invention, "electrical
25 equivalent" COP means the COP that the installation would have if electricity were used instead of gas or biofuel.

- AC generator: Device that generates alternating current either directly or through the intermediary of an additional converter that transforms the direct current
30 generated into alternating current.

- Combustion engine: Engine that, via combustion, transforms the chemical energy contained in a fuel into mechanical energy.

5 - Internal combustion engine: Combustion engine of which the combustion of the fuel producing the energy required for operation takes place in the engine itself, typically in a combustion chamber.

- Photovoltaic solar panel: Electrical generator of direct current constituted of a set of photovoltaic cells connected to each other electrically.

- Solar thermal collector: Device wherein the temperature of a solid, liquid or gas medium is increased by the total or partial absorption of solar radiation.

10 - Fuel cell: Device that produces electricity thanks to an electrode of a reducing fuel (for example hydrogen) coupled to the reduction on the other electrode of an oxidant, such as the oxygen in the air.

15 - "Cogeneration": unit formed of one or several machines de cogeneration, comprising one or several electricity generator units (of the thermal engine type + alternator and/or of the fuel cell type).

In the rest of this document, heat pump shall refer to a set formed of one or several circuits, or even one or several heat pumps themselves provided with one or several circuits.

20 Embodiments of the invention described here relate to a method of management that makes it possible to optimize the operation of an installation provided with a cogeneration machine, which may or may not be able to be connected to the network and a heat pump. The electricity coming from the cogeneration machine is used in particular, but not exclusively, for supplying the heat pump. The main desired value to respect is the thermal requirement, i.e. the heating power, but also optionally the cooling power and/or an electrical power, demanded by the system.

25 A few moderated electrical power auxiliaries can be added to this unit in such a way as to ensure the proper operation of it. This is typically circulation water pipes, lighting.

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It is desirable that embodiments of the invention provide for a method of regulating an installation comprising at least one cogeneration machine and at least one heat pump.

The installation to be regulated, described in reference to figures 1 and 2, comprises at least one cogeneration machine comprising a current generator unit which comprises either a
5 combustion engine (2) connected to an alternator (18) or a fuel cell. Each of the current generators comprises a heat exchanger (8) that produces very hot water at a temperature T2, said installation (1) or said current generator unit comprising, optionally, one or several other
10 current generators, selected from the group constituted by a combustion engine (2) connected to an alternator (18), a fuel cell (not shown), a photovoltaic solar panel (not shown), or a wind turbine.

The installation to be regulated also optionally comprises an electrical accumulator (19).

The installation to be regulated also comprises at least one heat pump (3), or a cooling unit, said heat pump or said cooling unit being either of the vapor compression type or of the
15 absorption type.

When said heat pump or said cooling unit is of the vapor compression type it comprises at least one

compressor (17) of coolant fluid, a first heat exchanger (11) located at the suction of the compressor (17) when the heat pump is in air conditioning mode, a pressure regulator (10), and a second heat exchanger (12) placed
5 at the discharge of the compressor (17) when the heat pump is in air conditioning mode. Said heat pump or said cooling unit further optionally comprises a third heat exchanger (15).

When said heat pump or said cooling unit is of the
10 absorption type, shown in figure 2, it then comprises an absorber (28), a circulation pump (30), a steam generator (29), a first heat exchanger (31) located at the inlet of said absorber (28), a pressure regulator (32) and a second heat exchanger (33) located at the outlet of said
15 steam generator (29).

The compressor (17) or the circulation pump (30) is driven by an electric motor, which can be supplied by one of said current generators.

The installation to be regulated comprises at least
20 one Pc Pa module referred to as "heat pump module" or at least one Pr module referred to as "refrigeration module" or at least one Pm module referred to as "mixed: heat pump and refrigeration".

If this entails a heat pump module by compression Pc,
25 each one of the at least one heat pump unit comprises at least one compressor (17) of coolant fluid, said first heat exchanger (11), said pressure regulator (10), said second heat exchanger (12).

If this entails a heat pump module by absorption Pa,
30 each one of the at least one heat pump unit comprises at least one absorber (28), said circulation pump (30), said steam generator (29), said first heat exchanger (31),

said pressure regulator (32) and said second heat exchanger (33);

If this entails a refrigeration module Pr, it comprises at least one cooling unit comprising at least
5 one compressor (17) of coolant fluid, said pressure regulator (10), said second heat exchanger (12), as well as coolant fluid pipes (16a, 16b) intended to be connected to an air/water exchanger of coolant fluid external to the Pr module.

10 If this entails a mixed module Pm, it comprises at least two units one of the heat pump type and the other of the cooling type, where the unit of the heat pump type comprises at least one compressor (17) of coolant fluid, said first heat exchanger (11), said pressure regulator
15 (10), said second heat exchanger (12), and the unit of the cooling type comprises at least one compressor (17) of coolant fluid, said pressure regulator (10), said second heat exchanger (12), as well as coolant fluid pipes (16a, 16b) intended to be connected to an air/water
20 exchanger of coolant fluid external to the module Pm.

In an embodiment, the installation to be regulated allows for the simultaneous production of very hot water at a temperature T2, of hot water at a temperature T1 and/or of cold water at a temperature T3, and of
25 electricity, and also optionally the production of coolant fluid at an evaporation temperature T4, and/or the production of coolant fluid at an evaporation temperature T5.

In an embodiment the cogeneration machine is a
30 combustion engine, more preferably an internal combustion engine. It is supplied more preferably by natural gas. According to the requirements, it can also be supplied by

other gaseous or liquid fuels such as gasoline, fuel oil, kerosene, alcohol, biofuels such as vegetable oils, bioethanol, biogas.

It can also entail other types of combustion engines, such as external combustion engines such as Stirling engines.

In another embodiment the cogeneration machine is a fuel cell. This can be any type of fuel cell known to those skilled in the art, operating typically, but not exclusively, at temperatures less than 200°C, but which can in certain cases reach a temperature from 800°C to 1000°C (for example a cell of the "solid oxide" type) and supplied by a suitable fuel, such as hydrogen, methane or a mixture of hydrocarbons such as gasoline or fuel. The fuel cell is comprised at least of one cell core supplied with hydrogen (the case with cores of fuel cells based on protonic membranes) or supplied by the plurality of fuels already mentioned (the case with high-temperature cell cores of the solid oxide type). If the cell is of the type based on protonic membranes and if the hydrogen is not directly available, then the fuel cell can be comprised of a reformer and of a cell core. The role of the reformer is to extract the hydrogen required for the cell core using more chemically complex fuels such as natural gas, methane, biogas or a mixture of hydrocarbons. The hydrogen extracted as such supplies the cell core based on protonic membranes.

In certain embodiments, the installation further comprises photovoltaic solar panels which can be any type of panel known to those skilled in the art, in particular, the semiconductor constituting the photovoltaic cells can be, in a non-restricted manner, amorphous silicon,

polycrystalline or monocrystalline, a semiconductor organic material, or a combination of the latter. A plurality of photovoltaic solar panels can be used.

In preferred embodiments, the heat pump of the installation is reversible, which means that it can operate in a mode that favors heating ("heating mode") or in a mode that favors
5 cooling ("air conditioning mode"). To do this, a four-way cycle reversing valve 46 (fig. 8c) is installed on the circuit of coolant fluid 16.

In the case where the heat pump 3 is reversible, the heat exchangers 11 and 12 are reversible exchangers.

The installation managed by the method is furthermore controlled by at least one
10 computing machine comprising at least one microprocessor and at least one data input interface. Data is entered into the microprocessor of said computing machine by the intermediary of said data input interface.

The computing machine that makes it possible to implement the method comprises a regulating software that is based on a data input interface. It is furthermore connected with the
15 required sensors, such as, but in a non-restricted manner, an outside temperature sensor, water outlet and inlet sensors, electrical power and/or intensity sensors, location sensors of the GPS type. Some of these sensors are present in the cogeneration machine and the heat pump by construction, other sensors are added according to the requirements linked to implementing the method. The computing machine also comprises if necessary electronic input/output boards,
20 calculation boards, communication boards of the GPRS or Internet/Ethernet type.

Regulation

Generally, this invention relates to a method for managing an installation comprising a cogeneration machine and a heat pump and a computing machine, said
5 method comprising the following steps:

(a) Data called "base data" are entered into said computing machine, said base data comprising at least the "resilience to electrical impact" of the cogeneration
10 machine, the "Imax" of the heat pump,

(b) Data called "instantaneous data" are entered into said computing machine, said instantaneous data comprising at least the state of the cogenerating machine, the state of the heat pump and the electrical power
15 demanded by the heat pump,

(c) Data called "target data" are defined to which are assigned a respective "target value" in said computing machine, said target data comprising at least the minimum consumption of primary energy and of
20 electricity by the installation, and one from among: the temperatures T1, T2, T3, T4, T5, and the electricity demand of the local network,

(d) the installation is regulated with the aid of said computing machine in such a way as to attain, for
25 each piece of the target data selected, the target value or values which have been assigned thereto, with the regulation being performed by comparing the current value of the piece of target data selected, by taking into account the base data selected as well as the
30 instantaneous data selected, and by adjusting at least one piece of "adjustment data", in such a way that the current value of each piece of target data selected is

made to approach the target value assigned to it in step c), with the at least one piece of adjustment data comprising the electrical power provided by the cogeneration machine.

5 In other embodiments, at least one additional piece of "base data" of the step (a) is selected in the group formed by (da1) the unit cost of the fuel of each combustion engine (2), fuel cell and absorption heat pump used in the system; (da2) the electrical content of each
10 fuel; (da3) the CO₂ impact of each fuel by unit of mass; (da4) the energy efficiency of each combustion engine (2) according to its load and its speed of rotation, which makes it possible to determine the quantity of CO₂ released per unit of mechanical power produced by this
15 combustion engine (2); (da5) the nominal power at full load of each combustion engine (2) according to its speed of rotation; (da6) the percentage of thermal power recovered on the cooling circuit of the combustion engine (2) and the percentage of thermal power recovered on the
20 exhaust gases and/or the quantity of CO₂ released per unit of thermal power produced by the combustion engine (2), (da7) the unit cost of the electrical energy provided by the external network; (da8) the service life of each generator according to its load; (da9) the
25 maintenance cost of each generator according to the number of hours of operation; (da10) the cost of disassembling and replacing each generator; (da11) the service life, the cost of maintenance, the cost of disassembling and replacing each type of heat pump; (da12)
30 the efficiency of the alternator according to the electrical power that it provides, which makes it possible to determine the mechanical power demanded of

the combustion engine (2) for an electrical power provided; (da13) the efficiency of the fuel cell according to its load; (da14) the efficiency of the inverter of the fuel cell or of the photovoltaic solar panels when they exist; (da15) the electrical consumption and the flow rate of the circulation pump of the solar collectors; (da16) the unit sales price of the electrical energy provided to the external networks;

In other embodiments, at least one additional piece of "instantaneous data" is selected in the group formed by: (db1) the instantaneous electrical power produced by each current generator present; (db2) the rotation speed of each combustion engine (2); (db3) the instantaneous consumption in fuel of the installation (1); (db4) the temperature of the fluid recovering the thermal energy of the combustion engine (2); (db5) the instantaneous electrical power consumed by the installation (1) with the network, obtained through a direct measurement; (db6) the instantaneous power provided to the network by the installation (1), obtained through a direct measurement; (db7) the current, the voltage or the instantaneous electrical power produced by the photovoltaic solar panel (if this panel is present); (db8) the instantaneous temperature T1; (db9) the instantaneous temperature T2; (db10) the instantaneous temperature T3; (db11) the instantaneous temperature T4 (db12) the instantaneous temperature T5 (db13) the temperature of the ambient air; (db14) the number of hours of operation of each electric current generator (mainly combustion engine 2 and fuel cell; (db15) the number of hours of operation of each heat pump circuit of the installation (vapor compression type or absorption type).

In other embodiments, at least one additional piece of "target data" is selected in the group formed by: (dc1) the temperature T1 and its change according to in particular the outside temperature; (dc2) the temperature
5 T2 and its change according to in particular the outside temperature; (dc3) the temperature T3 and its change according to in particular the outside temperature; (dc4) the temperature T4 and its change according to in particular the temperature desired in the desired in the
10 refrigerated space; (dc5) the temperature T5 and its change according in particular to the temperature desired in the refrigerated space (dc6) the global COP as being the maximum global COP for the installation (1) or the minimum global CO₂ impact of the installation (1); (dc7)
15 the energy cost as being the minimum energy cost of the installation (1); (dc8) the total operating cost as being the total minimum operating cost of the installation (1).

In other embodiments, at least one additional piece of "adjustment data" is selected in the group formed by:
20 (dd1) the type, the number of current generators in operation, and the electrical power provided by each of said generators; (dd2) the assigning of the electrical power provided by the generator or generators respectively to the installation and to the network
25 external to the installation (1); (dd3) the type and the number of heat pumps in operation; (dd4) in the case of vapor compression heat pumps, the volumetric flow rate adjustment (expressed as a percent) imposed by the regulation on the compressors in order to optimize the
30 installation (1).

The "current" value of the at least one piece of target data selected is determined from time to time or regularly or continuously.

In an advantageous embodiment, the tables of performances are entered for each type of heat pump giving the cooling power provided, the heating power provided, the electrical power consumed, the quantity of fuel consumed where applicable (case with the absorption heat pump) within its operating range. These performance tables are defined in fact by the water temperatures of each circuit (T1, T2 and T3, T4 and T5), the flow rate of the associated exchangers, and by the inlet temperature of the ambient air. The regulation mode can provide that any operation with one or several of these parameters outside if the defined operating range is prohibited.

In an advantageous embodiment, for each compressor used in vapor compression heat pumps, as an additional control, the following base data is entered:

- the tables of performance giving the cooling power provided,
- the heating power provided,
- the electrical power consumed according to the suction pressure and of the discharge pressure of the compressor for a given coolant fluid.

This data allows for an overlapping of the tables of performance hereinabove. It can also be used as base data in order to determine, for the full system, the cooling and heating power provided as well as the electrical power consumed by vapor compression heat pumps. This data integrates, for each compressor, the level of the volumetric flow rate (typically expressed as a percentage) at which it operates (typically from 10% to 100%).

The method of regulating of embodiments of this invention makes it possible to optimize the combined operation of cogeneration machines and of thermodynamic systems for example of the type of heat pumps that can come from the market and come from different suppliers, which is not the case of the method described in patent application WO 2011/01573.

5 The method uses the same general principles as those described in patent application WO 2011/01573 but takes moreover particularly into account a larger quantity of technical characteristics of cogeneration machines (in terms of power and data available) and of thermodynamic systems (in particular the possibility of having different types of compressors that can be encountered on the market: fixed-speed compressor without power regulation,
10 fixed-speed compressor but with power regulation, variable-speed compressor).

The method must take into account the following characteristics of the cogeneration machine:

- State of the operating modes of the cogeneration machine: On, Off or fault,
- Maximum power available according to the outside temperature, the altitude and
15 optionally other parameters linked to the engine;
- Resilience to the electrical impact to a value of maximum intensity that it is possible to produce (I_{max} available in amperes), i.e. the capacity to hold an I_{max} available typically demanded by the heat pump, and optionally by a local electrical network, by providing a sufficient level of quality of the current (instantaneous frequency and voltage). The resilience
20 to electrical impact generally characterizes the stability of an electrical system exposed to an increased instantaneous load (i.e. when the demand for current suddenly increases).

The method according to the invention must take into account the following characteristics of the heat pump:

- State of the operating modes: On, Off or fault
- 25 - Maximum value of intensity I_{max} demanded by the thermodynamic system. This value corresponds to the maximum sum of currents in the harshest conditions. This value is typically equal for a heat pump of n compressors to:

I_{\max} demanded by the thermodynamic system = I_{\max} demanded by each compressor + starting current of the last compressor chosen as being the one of larger size

- This value is proper to each heat pump, and is according to the operating conditions and the size and type of the components, in particular the compressor.

5 The method makes it possible to optimize the global operation of the installation. This optimization takes place over several aspects.

It first takes place on global efficiency, through the re-using of the heating power referred to as "fatal" on the generator but also through the optimization of the respective load of the generator or generators and of the load of the associated thermodynamic system or systems so that each one operates in the load range that provides a maximum associate global efficiency. The efficiencies of the gas-fueled thermal engines tend to increase with the load, those of compressors vary with the low and high pressure operating conditions but also according to their speed of rotation by passing in this latter case by a maximum.

15 It takes place on the operation itself of the systems in different conditions in order to ensure that the generator will be able to resist without stalling or excessive slowing down to the impact of the electrical load of the compressors. It can also limit the demand of compressors according to the capacity of the generator or generators. It also integrates degraded operating strategies that take into account the change in the thermal requirements and any limitations in performance of the generator or generators.

20 An advantage of the method of regulating is to give to the installation that it regulates a flexibility for use. The flexibility for use constantly allows for the optimum choice of the type or types of energy used and/or provided, according to external parameters and target parameters (objectives), subject to a suitable method of regulating.

25 The flexibility of use takes into account in particular the multiplicity of energies that can supply the various components of the system 1, as well as the multiplicity of the flows of energy that can be produced by the system 1. All of the modules hereinabove are supplied by one or several of the following energies: fossil fuels (in particular natural gas, liquefied petroleum gas, diesel, gasoline), biofuels, hydrogen and electrical current. Heat pumps

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modules can typically call upon the following two conventional cycles: the vapor mechanical compression cooling cycle and the absorption cycle. The conventional water networks

connected to the heat pumps can be supplemented in the device by a water network coming from the thermal solar collectors. Electricity generating modules can call upon various technologies of the thermal engine and alternator,
5 photovoltaic solar panel, wind turbine, turbine or fuel cell type.

The flexibility of use is made possible thanks to the global method of regulating the installation as a whole (heat pump and cogeneration machines) which allows
10 for the optimum taking into account of the following target parameters among others (objectives):

(i) Priority given to the COP of the installation. Configurable coefficients make it possible to express the various energies outside of the device (for example the
15 electricity of the network, the thermal energy of the solar collectors and the photovoltaic electric energy) in terms of primary energy and of the CO₂ impact in order to provide a global view of the COP of the installation. The regulation takes into account in the global optimization
20 the efficiency of the cogeneration machine. As such and among others operating rules:

- It is sought to operate the cogeneration machines in their maximum zone of efficiency (at full load for example for a thermal engine operating on natural gas);

25 - The maximum thermal discharge of the thermal engine is recovered. For example, if the requirements of the site for very hot water are less than the production of the thermal engine, this thermal production with hot water provided by the heat pump is accumulated;

30 - It is sought to operate all of the heat pump modules with a partial load rather than stopping some of them in order to reduce the load on each exchanger and as

such allow for more efficient operation from an energy standpoint.

(ii) Priority given to the energy operating cost of the installation:

5 The approach is similar to the preceding optimization, but the configurable coefficients for each type of energy become the following:

10 - Purchase cost of each energy outside of the device (typically electrical energy coming from the network or energy of the fossil fuel type or biogas) at the time of use. For example, the cost of the electrical energy can vary according to the period of the year but can also vary according to the consumption thresholds in the day or in the year, with this threshold or thresholds being
15 linked to the electrical subscription of the installation in question. These weightings can of course change over the service life of the installation and can therefore be configured in the framework of the global method of regulating the device.

20 - This device can optionally have its economic parameters updated by a centralized system that integrates the location of the equipment as well as climate projections that allow for a global optimization of the system over time or to receive function
25 impositions linked to one-off limitations of certain sources of energy.

30 - Any resale price to the electrical energy network that can if necessary be produced by the cogeneration machine or machines. This price can also vary, according to rules that are in general similar to those that apply to the purchase cost of electrical energy.

(iii) Priority given to the total operating cost of the installation (in particular the energy cost, the cost of maintenance which in particular includes the cost of disassembling and the cost of replacing). Particular importance is therefore given to the service life of certain critical components such as the combustion engines or fuel cells.

5 While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. It will be apparent to a person skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the present invention should not be limited by any of the above described
10 exemplary embodiments.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

15 The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

CLAIMS

1. Method for managing an installation comprising one or several cogeneration machines and one or several thermodynamic systems such as heat pumps, as well as at least one computing machine, said method comprising the following steps:
- 5 (a) Data called "base data" are entered into said computing machine, said base data comprising at least the resilience to the electrical impact of the cogeneration machine, and the value of maximum intensity of the heat
- 10 pump,
- (b) Data called "instantaneous data" are entered into said computing machine, said instantaneous data comprising at least the state of the cogenerating installation, the state of the heat pump and the
- 15 electrical power demanded by the heat pump,
- (c) Data called "target data" are defined to which are assigned a respective "target value" in said computing machine, said target data comprising at least the minimum and/or maximum production of electricity by the
- 20 installation, optionally the maximum consumption of electricity and of primary energy, and at least one from among: the temperatures of very hot water (T2), of hot water (T1), of cold water (T3), of evaporation of coolant fluid (T4, T5), and the electricity demand of the local
- 25 network,
- (d) the installation is regulated with the aid of said computing machine in such a way as to attain, for each piece of target data selected, the target value or values which have been assigned thereto, with the regulation
- 30 being performed by comparing the current value of the

piece of target data selected, by taking into account the base data selected as well as the instantaneous data selected, and by adjusting at least one piece of "adjustment data", in such a way as to approach the current value of each piece of target data selected of the target value assigned to it in step c), with the at least one piece of adjustment data comprising the electrical power provided by the cogeneration machine.

5

2. Method according to claim 1, wherein at least one additional piece of "base data" of the step (a) is selected in the group formed by (da1) the unit cost of the fuel of each combustion engine, fuel cell and absorption heat pump used in the system; (da2) the energy content of each fuel; (da3) the CO₂ impact of each fuel by unit of mass; (da4) the energy efficiency of each combustion engine according to its load and its speed of rotation, which makes it possible to determine the quantity of CO₂ released per unit of mechanical power produced by this combustion engine; (da5) the nominal power at full load of each combustion engine according to its speed of rotation; (da6) the percentage of thermal power recovered on the cooling circuit of the combustion engine and the percentage of thermal power recovered on the exhaust gases and/or the quantity of CO₂ released per unit of thermal power produced by the combustion engine, (da7) the unit cost of the electrical energy provided by the external network; (da8) the service life of each generator according to its load; (da9) the maintenance cost for each generator according to the number of hours of operation; (da10) the cost of disassembling and of replacing for each generator; (da11) the service life, the cost of maintenance, the cost of disassembling and replacing for each type of heat pump; (da12) the efficiency of the alternator according to the electrical power that it provides, which makes it possible to determine the mechanical power demanded of the combustion engine for an electrical power provided; (da13) the efficiency of the fuel cell according to its load; (da14) the efficiency of the inverter of the fuel cell or of the photovoltaic solar panels when they exist; (da15) the electrical consumption and the flow rate of the circulation pump of the solar collectors; (da16) the unit sales price of the electrical energy provided to the external network;

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3. Method according to claim 1 or 2, wherein at least one piece of additional "instantaneous data" is selected in the group formed by: (db1) the instantaneous electrical power produced by each current generator present; (db2) the rotation speed of each combustion engine; (db3) the instantaneous consumption in fuel of the installation; (db4) the

30

temperature of the fluid recovering the thermal energy of the combustion engine; (db5) the instantaneous electrical power consumed by the installation with the network, obtained through a direct measurement; (db6) the instantaneous power provided to the network by the installation, obtained through a direct measurement; (db7) the current, the voltage or the instantaneous electrical power produced by the photovoltaic solar panel (if this panel is present); (db8) the instantaneous temperature T1; (db9) the instantaneous temperature T2; (db10) the instantaneous temperature T3; (db11) the instantaneous temperature T4 (db12) the instantaneous temperature T5 (db13) the temperature of the ambient air; (db14) the number of operating hours of each electric current generator (mainly combustion engine and fuel cell); (db15) the number of operating hours of each heat pump circuit of the installation (of the vapor compression or absorption type).

4. Method according to one of the preceding claims, wherein at least one additional piece of "target data" is selected in the group formed by: (dc1) the temperature T1 and its change; (dc2) the temperature T2 and its change; (dc3) the temperature T3 and its change; (dc4) the temperature T4 and its change; (dc5) the temperature T5 and its change; (dc6) the global COP as being the maximum global COP for the installation or the minimum global CO₂ impact of the installation; (dc7) the energy cost as being the minimum energy cost of the installation; (dc8) the total operating cost as being the total minimum operating cost of the installation.

5. Method according to claim 4, wherein at least one additional piece of "target data" is the change in temperature T1 according to the outside temperature.

6. Method according to claim 4 or claim 5, wherein at least one additional piece of "target data" is the change in temperature T2 according to the outside temperature.

7. Method according to any one of claims 4 to 6, wherein at least one additional piece of "target data" is the change in temperature T3 according to the outside temperature.

8. Method according to any one of claims 4 to 7, wherein at least one additional piece of "target data" is the change in temperature T4 according to the temperature desired in the refrigerated space.

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9. Method according to any one of claims 4 to 8, wherein at least one additional piece of "target data" is the change in temperature T5 according to the temperature desired in the refrigerated space.
10. Method according to one of the preceding claims, wherein at least one additional piece of "adjustment data" is selected in the group formed by: (dd1) the type, the number of current generators in operation, and the electrical power provided by each one of said generators; (dd2) the assigning of the electrical power provided by the generator or generators respectively to the installation and to the network external to the installation; (dd3) the type and the number of heat pumps in operation; (dd4) in the case of vapor compression heat pumps, the volumetric flow rate adjustment (expressed as a percent) imposed by the regulation on the compressors in order to optimize the installation.
11. Method according to one of the preceding claims, wherein the "current" value of the at least one piece of target data selected is determined from time to time or regularly or continuously.
12. Method according to one of the preceding claims, wherein said base data can be entered into the computing machine either when it is initially programmed, or when the installation is put into service, or by the user of the installation, over the course of time during the use of the installation.

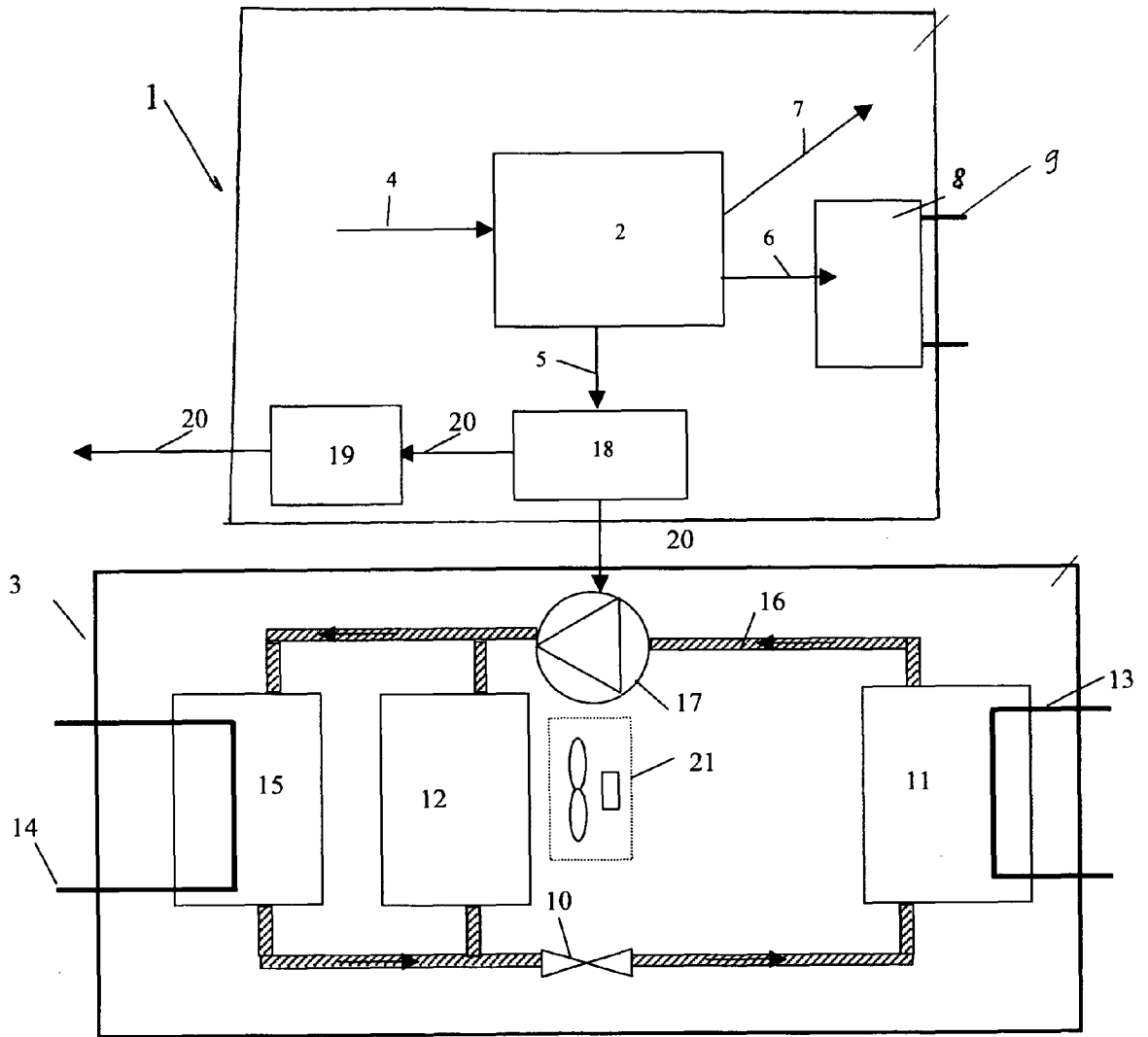


Figure 1

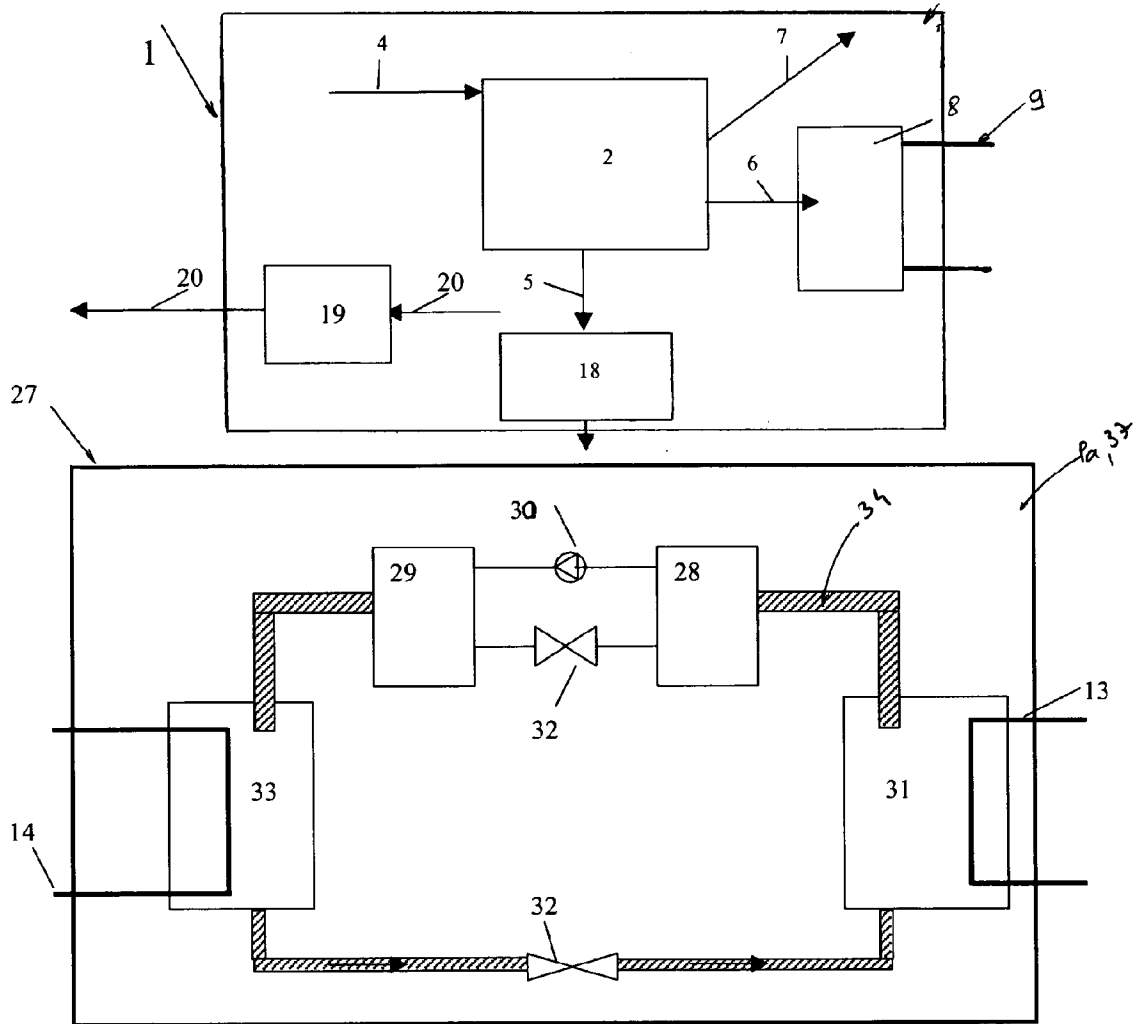


Figure 2