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(54) METHOD FOR CONTROLLING THE OPERATION OF A HYBRID HEATING PLANT TO HEAT A GAS AND HYBRID HEATING PLANT THEREOF

(57) It is disclosed a method for controlling the set-point temperature (Tset_PdC) of the delivery water of a heat pump (3) of a hybrid heating plant (1) comprising a gas boiler (4) operating in combination with the heat pump to heat a gas by means of a heat exchanger. The method comprises the steps of: acquiring (102) values indicative of the temperature of the return water (Tr_w) of the heat exchanger (5), of the temperature of the gas (T_gas), of the flow rate of the water (Fm_o_PdC) associated with the heat pump, the operating state of the heat pump and the operating state of the gas boiler; detecting a switched on or off operating state of the gas boiler in a defined time interval; checking (103) whether the heat pump is active or inactive; calculating (108) a maximum value of the setpoint temperature of the delivery water (Tset_PdC) of the heat pump (3) and setting said calculated maximum value for the setpoint temperature of the delivery water (Tset_PdC) of the heat pump, so that the heat pump operates at a maximum thermal power mode; changing (109) the value of the setpoint temperature of the delivery water of the heat pump between a minimum value and said calculated maximum value of the setpoint temperature, so that the heat pump operates at a modulated thermal power mode.

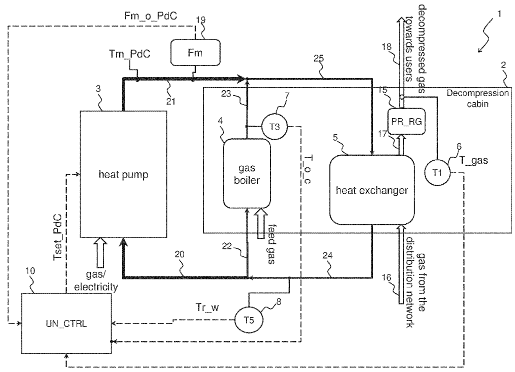

Fig. 1

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention generally concerns the field of controlling the operation of a hybrid heating plant comprising a gas heating system and at least one heat pump.

[0002] More particularly, the present invention concerns a method for controlling the setpoint temperature of the delivery water of the at least one heat pump.

PRIOR ART

[0003] Hybrid heating plants comprising a gas heating system consisting of one or more gas boilers (traditional or condensing ones) and one or more electrically or gas fed heat pumps are known.

[0004] The Applicant has observed that the hybrid heating plants used for gas decompression are not optimised in terms of energy consumption, as the gas boilers are oversized and therefore reduce the operating range of the heat pumps.

[0005] Furthermore another disadvantage of the known hybrid heating plants used for gas decompression is that they have instability in the temperature of return of the water from the heat exchanger, which decreases the efficiency of the plant.

[0006] In addition, another disadvantage of the hybrid heating plants used for gas decompression is that they have excessive operating instability due to the discontinuous activation of the oversized boilers.

SUMMARY OF THE INVENTION

[0007] The present invention concerns a method for controlling the setpoint temperature of the delivery water of a heat pump of a hybrid heating plant used to heat a gas, wherein the control method is defined in the appended claim 1 and by preferred embodiments thereof described in dependent claims 2 to 10.

[0008] It is also an object of the present invention a non-transitory computer-readable storage medium as defined in the appended claim 11.

[0009] It is also an object of the present invention a hybrid heating plant used to heat a gas as defined in the appended claim 12 and by preferred embodiments thereof as defined in the appended claim 13.

[0010] The Applicant has perceived that the method for controlling the setpoint temperature of the delivery water of the heat pump of the hybrid heating plant and relative hybrid heating plant according to the present invention has the advantage of optimising the energy consumption of the plant (for example in terms of gas consumption), maximizing the equivalent hours of operation at full speed of the heat pumps and maximizing the efficiency thereof, i.e. minimizing the minimum setpoint temperature of the delivery water of the heat pumps and stabilizing the switching from a maximum thermal power operating mode to a modulated thermal power operating mode and vice versa.

[0011] It is also an object of the present invention a computer program comprising software code portions adapted to perform the steps of the method for controlling the setpoint temperature of the delivery water of the heat pump of a hybrid heating plant according to the invention, when said program is run on at least one computer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Figure 1 shows a block diagram of a hybrid heating plant according to an embodiment of the invention.

Figures 2A-2B show a flowchart of a method for controlling the operation of the hybrid heating plant of Figure 1.

Figure 3 shows a flowchart of the method for calculating the maximum value of the setpoint temperature of the delivery water of a heat pump of the hybrid heating plant of figure 1.

Figures 4A-4B schematically show a possible trend of the setpoint temperature of the delivery water of the heat pump, of the actual temperature Tm_PdC of the delivery water of the heat pump and of the actual temperature Tr_w of the return water of the heat exchanger, when the heat pump operates at the maximum thermal power mode.

Figure 5A schematically shows a possible trend of the setpoint temperature of the delivery water of the heat pump and of the minimum and maximum values of the setpoint temperature of the delivery water of the heat pump, when it operates at the modulated thermal power mode.

Figure 5B schematically shows a possible trend of the minimum and maximum values of the setpoint temperature of the delivery water of the heat pump, during the transient phase in which the operation of the heat pump switches from the maximum thermal power mode to the modulated thermal power mode.

DETAILED DESCRIPTION OF THE INVENTION

[0013] It should be observed that, in the following description, identical or analogous blocks are indicated in the figures with the same numerical references.

[0014] With reference to Figure 1, a block diagram of a hybrid heating plant 1 according to an embodiment of the invention is shown.

[0015] The heating plant 1 comprises a gas boiler 4, a heat pump 3, a heat exchanger 5 and a gas pressure regulator 15.

[0016] The heating plant 1 further comprises two water temperature sensors 7 and 8, a gas temperature sensor 6, a water flow meter 19 and a control unit 10 electrically connected to the sensors 6, 7, 8 and to the water flow meter 19.

[0017] For the purpose of explaining the invention, only one gas boiler is considered for simplicity's sake, but more generally the invention is also applicable to the case in which two or more gas boilers operating in parallel are present.

[0018] Similarly, for the purpose of explaining the invention a single heat pump is considered for simplicity's sake, but more generally the invention is also applicable to the case in which two or more heat pumps operating in parallel are present.

[0019] The heat pump 3 operates in combination (i.e. in parallel) with the gas boiler 4 in order to supply thermal power to the heat exchanger 5, by means of an appropriate control of the operation of the temperature of the delivery water of the heat pump 3, as will be explained in more detail below.

[0020] The heating plant 1 has the function of heating a gas flow before it is decompressed, in order to distribute it to civil and/or industrial users with an appropriate pressure value.

[0021] For this purpose the heat exchanger 5 is thermally coupled with an inlet pipe 16 adapted to receive a gas flow from a gas distribution network and is thermally coupled with an outlet pipe 17 adapted to generate a heated gas flow.

[0022] The pressure regulator 15 is connected to the outlet pipe 17 and has the function of decompressing the heated gas, generating at the outlet a decompressed gas carried in a pipe 18 feeding civil and/or industrial users.

[0023] For the purposes of explaining the invention, the case is considered in which the gas is heated to reduce its pressure with the aim of distributing the gas to civil or industrial users: in this case the gas boiler 4, the heat exchanger 5 and the pressure regulator 15 are enclosed within a same gas decompression cabin.

[0024] Note, however, that the invention may also be used in other applications where a reduction in gas pressure in a pipe is required.

[0025] The gas boiler 4 comprises an inlet pipe 22 adapted to carry cold water received from the heat exchanger 5 and comprises an outlet pipe 23 adapted to carry hot water towards the heat exchanger 5.

[0026] The heat pump 3 comprises an inlet pipe 20 adapted to carry cold water received from the heat exchanger 5: the water flowing in the inlet pipe 20 will be hereinafter referred to as "return water" of the heat pump 3.

[0027] The heat pump 3 further comprises an outlet pipe 21 adapted to carry hot water towards the heat exchanger 5: the water flowing in the outlet pipe 21 will be hereinafter referred to as "delivery water" of the heat pump 3.

[0028] The heat pump 3 receives at the inlet from the control unit 10 a control signal carrying a value Tset_PdC of the setpoint (i.e. setting) temperature of the delivery water of the heat pump 3, thus the heat pump 3 modifies its operation so as to generate on the outlet pipe 21 a flow of delivery hot water having an actual temperature Tm_PdC chasing said value Tset_PdC of the setpoint temperature.

[0029] The heat pump 3 can be electrically powered, in the case of operation with compression of a fluid.

[0030] Alternatively, the heat pump may be fed with gas, in the case of absorption of heat from a fluid.

[0031] The heat exchanger 5 comprises an inlet pipe 25 adapted to carry hot water received from the assembly of the pipe 23 of the gas boiler 4 and of the pipe 21 of the heat pump 3.

[0032] The heat exchanger 5 further comprises an outlet pipe 24 adapted to carry cold water towards the pipe 22 of the gas boiler 4 and towards the heat pump pipe 20.

[0033] The heat exchanger 5 is for example a water/gas exchanger which receives at the inlet the hot water flowing through the inlet pipe 25 and generates at the outlet cold water flowing through the pipe 24: by means of the heat exchanger 5 heat is transferred from the hot water in the heat exchanger 5 to the gas, which is then heated and sent in the outlet pipe 17.

[0034] The water flowing in the outlet pipe 24 of the heat exchanger 5 will hereinafter be referred to as "return water" of the heat exchanger 5.

[0035] The heat exchanger may be a tube bundle, i.e. formed by a tube bundle placed inside a cylindrical-shaped container (called shell), in which a fluid (in particular, water) flows inside the tubes, while another fluid (in particular, gas) flows in the space delimited between the inner surface of the shell and the outer surfaces of the tubes, thus transferring heat between the two fluids.

[0036] The water temperature sensor 8 is coupled to the pipe 24 at the outlet from the heat exchanger 5 and it has the function of detecting the temperature of the return water of the heat exchanger 5, i.e. the temperature of the cold water carried by the pipe 24 at the outlet from the heat exchanger 5, generating a water temperature signal Tr_w indicative of the temperature of the return water of the heat exchanger 5.

[0037] Alternatively, the temperature sensor 8 is coupled to the pipe 20 at the inlet to the heat pump 3 and has the function of detecting the temperature of the cold water carried by the pipe 20 at the inlet to the heat pump 3.

[0038] Alternatively, the temperature sensor 8 is coupled to the pipe 22 and has the function of detecting the temperature of the cold water carried by the pipe 22 at the inlet to the gas boiler 4.

[0039] The gas temperature sensor 6 has the function of detecting the current temperature of the decompressed gas flow in the pipe 18, generating a gas temperature signal T_gas indicative of the current temperature of the decompressed gas flow carried in the pipe 18.

[0040] Alternatively, the gas temperature sensor 6 can be mounted on the pipe 17 located directly at the outlet of the heat exchanger 5: in this case the gas temperature sensor 6 has the function of detecting the temperature of the heated gas flow carried by the pipe 17 directly connected at the outlet from the heat exchanger 5, i.e.

before gas decompression.

[0041] The water temperature sensor 7 has the function of detecting the temperature of the delivery water of the gas boiler 4 (i.e. the temperature of the hot water carried by the pipe 23 connected at the outlet to the gas boiler 4), generating a further water temperature signal T_o_c indicative of the temperature of the delivery water of the gas boiler 4.

[0042] The temperature T_o_c of the delivery water of the gas boiler 4 is for example comprised between 40 degrees centigrade and 80 degrees centigrade.

[0043] Furthermore, the heating plant 1 comprises a water flow sensor 19 (inside or outside the heat pump 3) generating a water flow signal Fm_o_PdC indicative of the flow rate of the water associated with the heat pump 3, in particular the flow rate of the delivery water flowing in the pipe 21 at the outlet from the heat pump 3.

[0044] The control unit 10 has the function of controlling the operation of the heat pump 3 in combination with the gas boiler 4, in order to optimise the gas consumption of the plant 1, maximizing the operating hours of the heat pump 3 (i.e. maximizing the thermal power delivered by the heat pump 3) and maximizing its efficiency, since the minimum value of the setpoint temperature of the delivery water of the heat pump 3 is minimized and the switching of the heat pump 3 from the maximum thermal power to the modulated thermal power operating mode (and vice versa) is stabilized.

[0045] The control unit 10 is for example a microprocessor executing a suitable software program.

[0046] Alternatively, the control unit 10 is a microcontroller or a PLC (Programmable Logic Controller).

[0047] The control unit 10 is electrically connected to the heat pump 3, to the water temperature sensors 7, 8, to the gas temperature sensor 6 and to the water flow meter 19.

[0048] In particular, the control unit 10 comprises one or more inlet terminals adapted to receive the values measured by the sensors 8, 7, 6 and by the water flow meter 19, i.e. the water temperature signal Tr_w indicative of the temperature of the return water of the heat exchanger 5, the further water temperature signal T_o_c indicative of the temperature of the delivery water of the gas boiler 4, the gas temperature signal T_gas indicative of the current temperature of the decompressed gas carried in the pipe 18 and the water flow signal Fm_o_PdC indicative of the flow rate of the water associated with the heat pump 3 (for example, the delivery water).

[0049] The control unit 10 further comprises an outlet terminal adapted to generate the control signal carrying the value Tset_PdC of the setpoint (i.e. setting) temperature of the delivery water of the heat pump 3, wherein said value Tset_PdC is used by the heat pump 3 to modify its operation in order to generate at the outlet delivery hot water having an actual temperature Tm_PdC chasing said value Tset_PdC.

[0050] The control unit 10 is configured to calculate the following internal variables, which will then be used to calculate the setpoint temperature Tset_PdC of the delivery water of the heat pump 3:

- operating state of the gas boiler 4, i.e. switched on or off;
- operating state of the heat pump 3, i.e. active or inactive;
- time interval elapsed since the last switching on of the gas boiler 4: it is a counter that counts how long the gas boiler 4 has been switched off and is reset when the operating state of the gas boiler 4 is switched on.

[0051] In particular, the control unit 10 is configured to control the operation of the heat pump 3 so that it operates at least according to the following operating modes:

- a normal modulated thermal power operating mode, in which a modulation (i.e. a variation) of the power delivered by the heat pump 3 is performed by means of a modulation (i.e. a variation) of the value of the setpoint temperature Tset_PdC of the delivery water of the heat pump 3 between a minimum value Tset_PdC_min and a maximum value Tset_PdC_max of the setpoint temperature, as shown by lines 210 (Tset_PdC), 211 (Tset_PdC_min) and 212 (Tset_PdC_max) of Figure 5A;
- a maximum thermal power operating mode, in which the value of the setpoint temperature of the delivery water of the heat pump 3 is set equal to a maximum value Tset_PdC_max varying over time, as shown by line 202 of Figure 4A and by line 202a of Figure 4B;
- a stand-by mode, in which the value of the setpoint temperature of the delivery water of the heat pump 3 is set at a sufficiently small value (for example, equal to 20 degrees);
- switched off mode, in which the value of the setpoint temperature of the delivery water of the heat pump 3 is set as a value such as to switch off the heat pump (for example, a substantially null value, i.e. about 0 degrees).

[0052] Note that for the purpose of explaining the invention only one gas boiler 4 and one heat pump 3 has been shown in Figure 1, but more generally the invention is also applicable to the case in which the hybrid heating plant 1 comprises two or more gas boilers analogous to the gas boiler 4 and/or two or more heat pumps analogous to the heat pump 3: in this case, therefore, two or more heat pumps operate in parallel to the two or more gas boilers.

[0053] With reference to Figures 2A-2B, a flowchart 100 of the method for controlling the operation of the hybrid heating plant 1 is shown.

[0054] The flowchart 100 is executed by means of a suitable software program (or firmware) executed on the control unit 10 of the hybrid heating plant 1.

[0055] The flowchart 100 is repeated at defined time intervals, in particular periodically, for example with an interval equal to 2 seconds.

[0056] The flowchart 100 starts with step 101.

[0057] Step 101 is followed by step 102 in which the values indicative of the temperature of the return water Tr_w of the heat exchanger 5, of the temperature of a gas T_gas to be decompressed or decompressed and of the flow rate of the water Fm_o_PdC associated with the heat pump 3 are acquired at a certain time instant.

[0058] Furthermore, in step 102, the switched on or off operating state of the gas boiler 4 (operating in parallel with the heat pump 3) is detected in the last period of time, i.e. in a defined time interval preceding the determined time instant in which the data from the sensors indicated above were acquired.

[0059] Finally, in step 102, the operating state of the heat pump 3 is acquired.

[0060] The switched on or off operating state of the gas boiler 4 can be detected for example by detecting the temperature of the water at the outlet from the gas boiler 4 (i.e. the temperature of the delivery water T_o_c of the gas boiler 4, i.e. the temperature of the water carried by the pipe 23 at the outlet from the gas boiler 4) and by detecting the temperature of the water at the inlet to the gas boiler 4.

[0061] In particular, the switched on/off operating state of the gas boiler 4 is detected by comparing the difference between the temperature of the water at the outlet from the gas boiler 4 (i.e. the temperature T_o_c of the delivery water of the gas boiler 4) and the temperature of the water at the inlet to the gas boiler 4 (i.e. the temperature of the water in the pipe 22 at the inlet of the gas boiler 4 or in the pipe 24 at the outlet from the heat exchanger 5) and a value of a boiler activation temperature threshold (for example, 4 degrees centigrade):

- in the case in which the value of said difference is greater than or equal to the value of the boiler activation temperature threshold, the state of the gas boiler 4 is switched on;
- in the case in which the value of said difference is lower than the value of the boiler activation temperature threshold, the state of the gas boiler 4 is switched off.

[0062] Alternatively, the switched on/off state of the gas boiler 4 can be detected by means of a magnetometer, a magnetic field meter, a vibration tester or by connecting with the regulator inside the gas boiler 4 and retrieving its operating state.

[0063] Step 102 is followed by step 103 in which it is checked whether the heat pump 3 is active:

- in the case in which the heat pump 3 is active, step 103 is followed by step 104;
- in the case in which the heat pump 3 is inactive, step 103 is followed by step 105.

[0064] The active or inactive operating state of the heat pump 3 is updated (see next steps 104 and 105) as a function of the temperature of the gas T_gas with respect to the first setpoint temperature value of the gas T1_set_gas (see next step 104) and as a function of the temperature of the gas T_gas with respect to the second setpoint temperature value of the gas T2_set_gas (see next step 105).

[0065] In step 104 it is checked whether the value of the temperature of the gas T_gas (decompressed or to be decompressed) is lower than a first setpoint temperature value of the gas T1_set_gas (for example, T1_set_gas is equal to 12 degrees centigrade):

- in the case in which the value of the temperature of the gas T_gas is lower than the first setpoint temperature value of the gas T1_set_gas, it is proceeded from step 104 to step 106;
- in the case in which the value of the temperature of the gas T_gas is greater than or equal to the first setpoint temperature value of the gas T1_set_gas, it is proceeded from step 104 to step 107.

[0066] Similarly, in step 105 it is checked whether the value of the temperature of the gas T_gas (decompressed or to be decompressed) is lower than a second setpoint temperature value of the gas T2_set_gas lower than the first setpoint temperature value of the gas (for example, equal to 10 degrees centigrade):

- in the case in which the value of the temperature of the gas T_gas is lower than the second setpoint temperature value of the gas T2_set_gas, it is proceeded form step 105 to step 106;
- in the case in which the value of the temperature of the gas T_gas is greater than or equal to the second setpoint temperature value of the gas T2_set_gas, it is proceeded from step 105 to step 107.

[0067] The use of two different values T1_set_gas, T2_set_gas of the setpoint temperature of the gas defines a hysteresis having the advantage of reducing the frequency of the switching on or off of the gas boiler 4.

[0068] In addition, in steps 104 and 105, the operating state of the heat pump 3 is updated:

- in case of negative response in steps 104 and 105, the state of the heat pump 3 switches to inactive or remains inactive;
- in case of positive response in steps 104 and 105, the state of the heat pump 3 switches to active or remains active.

[0069] In step 106 it is checked whether the gas boiler 4 has always been switched off in the last period of time (i.e. in a defined time interval preceding the time instant in which the values from the temperature sensors were acquired):

- in the case in which the gas boiler 4 has always been switched off in the last period of time, step 106 is followed by step 109;
- in the case in which the gas boiler 4 has not always been switched off in the last period of time (i.e. it has been switched on at least once), step 106 is followed by step 108.

[0070] Similarly, in step 107 it is checked whether the gas boiler 4 has always been switched off in the last period of time (i.e. in a defined time interval preceding the time instant in which the values from the temperature sensors were acquired):

- in the case in which the gas boiler 4 has always been switched off in the last period of time, step 107 is followed by step 111;
- in the case in which the gas boiler 4 has not always been switched off in the last period of time (i.e. it has been switched on at least once), step 107 is followed by step 110.

[0071] In step 108 the heat pump 3 operates at a maximum thermal power mode in which the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 chases a maximum value Tset_PdC_max of the setpoint temperature of the delivery water varying over time, as shown in Figures 4A (line 202) and 4B (line 202a).

[0072] In particular, in step 108 a maximum value Tset_PdC_max of the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 is calculated as a function of the temperature of the return water Tr_w of the heat exchanger 5 and of the flow rate of the water Fm_o_PdC associated with the heat pump 3, then said calculated maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 is set.

[0073] For example, the calculated maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 has values comprised between 45 and 53 degrees centigrade and is continuously updated as a function of the temperature of the value of the return water Tr_w of the heat exchanger 5 and of the flow rate of the water Fm_o_PdC associated with the heat pump 3.

[0074] In particular, said calculation and setting of the maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 is carried out by means of the control unit 10, which generates the control signal Tset_PdC equal to the calculated maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3, which receives said calculated maximum value Tset_PdC_max in input and modifies its operation so as to generate on the outlet pipe 21 a delivery hot water flow having an actual temperature Tm_PdC chasing said calculated maximum value Tset_PdC_max.

[0075] Step 108 will be explained in more detail below with reference to the description of Figure 3.

[0076] In step 109 the heat pump 3 operates at a modulated thermal power mode in which the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 varies over time and is comprised between a minimum value Tset_PdC_min and the maximum value Tset_PdC_max, as shown in Figure 5A.

[0077] In particular, in step 109 a variation over time of the value of the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 is calculated as a function of an acquired value of the temperature of the gas T_gas and of a value of a regulation setpoint temperature of the gas Treg_set_gas, wherein said variation is comprised between a minimum value Tset_PdC_min and the maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 (the latter calculated in step 108), then said variation over time of the calculated value of the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 is set.

[0078] Therefore in the flowchart 100 we arrive at step 108 in which the heat pump 3 operates at maximum power in the case in which the temperature of the (decompressed or to be decompressed) gas is low and furthermore the gas boiler 4 has been switched on (at least in part) in the considered last period of time.

[0079] Otherwise, we arrive at step 109 in which the heat pump 3 operates with a fine variation of the power delivered between a minimum and maximum value that are variable over time, in the case in which the temperature of the (decompressed or to be decompressed) gas is low and furthermore the gas boiler 4 has always been switched off in the considered last period of time.

[0080] This has the advantage of optimising the power consumption of the hybrid heating plant 1 and of reducing the instability of operation of the plant, as the time interval at full speed of the heat pump 3 is increased and the number of switchings the gas boiler 4 on is reduced.

[0081] A part of step 109 (in particular the calculation of the maximum value T_set_PdC_max of the setpoint temperature of the delivery water) will be explained in more detail below with reference to the description of Figure 3.

[0082] In step 110 the heat pump 3 is set in a stand-by state, by setting the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 to a sufficiently low value (for example, equal to 20 degrees centigrade), in which the heat pump 3 is active but does not consume gas or electricity.

[0083] In step 111 the heat pump 3 is switched off, by setting the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 to a very low value (for example, equal to about 0 degrees centigrade).

[0084] Thus in the flowchart 100 we arrive at step 110 in which the heat pump 3 is in a stand-by state in the case in which the temperature of the (decompressed or to be decompressed) gas is high and furthermore the gas boiler 4 has been switched on (at least in part) in the last period of time considered; otherwise, we arrive at step 111 in which the heat pump 3 is switched off, in the case in which the temperature of the (decompressed or to be decompressed) gas is high and furthermore the gas boiler 4 has always been switched off in the last period of time considered.

[0085] This has the advantage of allowing a quick activation of the heat pump 3, minimizing its energy consumption.

[0086] In the case in which two or more gas boilers operating in combination with two or more heat pumps are present, the flow rate of the water associated with the two or more heat pumps is acquired in step 101 and the switched on or off operating state of the two or more heat pumps is acquired.

[0087] Furthermore, in step 102, the active or inactive operating state of the two or more heat pumps is detected and in step 103 it is checked whether at least one heat pump is active.

[0088] In steps 106 and 107 it is checked whether all two or more gas boilers have always been switched off in the last period of time.

[0089] Finally, in step 108 the maximum value of the setpoint temperature of the delivery water for the two or more heat pumps is set and in step 109 the variation over time of the calculated value of the setpoint temperature of the delivery water for the two or more heat pumps is set.

[0090] From steps 108, 109, 110 and 111 a return to step 102 is made and the data acquisition cycle of the sensors, the calculation of the setpoint temperature of the delivery water of the heat pump, the acquisition of the operating state of the heat pump 3 and the gas boiler 4 are started again.

[0091] With reference to Figure 3, it shows a flowchart 150 of the method for calculating the maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 of the hybrid heating plant 1, when the heat pump 3 operates at the maximum thermal power mode (step 108 illustrated above) or when the heat pump 3 operates at the modulated thermal power mode (step 109 illustrated above).

[0092] The maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 is used when the heat pump 3 operates at the modulated thermal power mode (step 109 illustrated above) to define the maximum value of the temperature modulation interval of the delivery water of the heat pump 3.

[0093] Therefore the flowchart 150 shows in more detail step 108 and a part of step 109 of the flowchart 100 of Figure 2B.

[0094] The flowchart 150 is executed by means of a suitable software program (or firmware) executed on the control unit 10 of the plant 1.

[0095] The flowchart 150 starts with step 151.

[0096] Step 151 is followed by step 152 in which a plurality of values of a statistical index of the temperature of the return water Tr_w of the heat exchanger 5 are calculated in a respective plurality of defined time intervals.

[0097] The statistical index is for example the mean, the mode or the median.

[0098] Step 152 is followed by step 153 in which it is checked whether the current value of the temperature of the return water Tr_w of the heat exchanger 5 is lower than the set value of a setpoint temperature of the return water of the heat exchanger 5:

- in the case in which the current value of the temperature of the return water Tr_w of the heat pump 3 is lower than the set value of the setpoint temperature of the return water of the heat exchanger 5, step 153 is followed by step 154;
- in the case in which the current value of the temperature of the return water Tr_w of the heat exchanger 5 is greater than or equal to the set value of the setpoint temperature of the return water of the heat exchanger 5, step 153 is followed by step 155.

[0099] In step 154, the trend of the plurality of calculated values of the statistical index of the temperature of the return water is analysed as the respective plurality of defined time intervals vary:

- in the case in which the trend is increasing, step 154 is followed by step 158;
- in the case in which the trend is decreasing, step 154 is followed by step 156.

[0100] Similarly, in step 155, the trend of the plurality of calculated values of the statistical index of the temperature of the return water is analysed as the respective plurality of defined time intervals vary:

- in the case in which the trend is decreasing, step 155 is followed by step 158;
- in the case in which the trend is increasing, step 155 is followed by step 157.

[0101] In step 156 the maximum value of the setpoint temperature Tset_PdC_max of the delivery water of the heat pump 3 is decreased.

[0102] Furthermore, in step 156 the value of the setpoint temperature of the return water of the heat exchanger 5 is decreased as a function of the objective power of the heat pump 3 and of the flow rate of the water Fm_or_PdC associated with the heat pump 3.

[0103] From step 156 a return to step 152 is made and the calculation method starts over as illustrated above.

[0104] The objective power of the heat pump 3 is a specific value of the heat pump 3 and is chosen as a function of the particular operating conditions.

[0105] In particular, at low external temperature or at high operating temperature of the delivery water, the power delivered by the heat pump 3 decreases, thus the objective power of the heat pump 3 is slightly lower than the nominal power of the heat pump 3.

[0106] In step 157 the maximum value of the setpoint temperature Tset_PdC_max of the delivery water of the heat pump 3 is increased.

[0107] Furthermore in step 157 the value of the setpoint temperature of the return water of the heat exchanger 5 is increased as a function of the objective power of the heat pump 3 and of the flow rate of the water Fm_o_PdC.

[0108] From step 157 a return to step 152 is made and the calculation method starts over as illustrated above.

[0109] The maximum value of the setpoint temperature Tset_PdC_max of the delivery water of the heat pump 3 has thus a variable value over time, both when the heat pump 3 operates at the modulated power mode (see dashed line 212 of Figure 5A and the solid line 222 of Figure 5B), and when this operates at the maximum power mode (see line 202 in Figure 4A and line 202a in Figure 4B).

[0110] In one embodiment, in step 156 the maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 is further decreased by further taking into consideration the past values of the temperature of the return water Tr_w of the heat exchanger 5 and in step 157 the maximum value Tset_PdC_max of the setpoint temperature is further increased by further taking into consideration the past values of the temperature of the return water Tr_w.

[0111] In one embodiment, the heat pump 3 operates at constant flow rate: in this case in steps 156 and 157 the value of the setpoint temperature of the return water of the heat exchanger 5 is updated only as a function of the value ΔT_in_out of the desired water temperature difference between the inlet pipe 20 and the outlet pipe 21 of the heat pump 3, which in turn depends on the desired power and on the flow rate of the heat pump 3.

[0112] In step 158 the maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 is kept unchanged.

[0113] The flowchart 150 is repeated at defined time intervals, for example periodically, in order to dynamically update over time the maximum value Tset_Pdc_max of the setpoint temperature of the delivery water of the heat pump 3.

[0114] The calculation method illustrated above relating to the maximum value of the setpoint temperature of the delivery water of the heat pump 3 has the advantage of minimizing the operating instability caused by the discontinuous activation of the gas boiler 4.

[0115] When the heat pump 3 operates at the modulated thermal power mode (step 109 of the flowchart 100), the value of the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 varies between a minimum value Tset_PdC_min and the maximum value Tset_PdC_max, as shown by the solid line 210 of Figure 5A.

[0116] In particular, in the modulated thermal power mode the value of the setpoint temperature Tset_PdC of the delivery water of the heat pump 3 is regulated by means of a Proportional-Integrative type controller which receives the value of the temperature of the gas T_gas in input and makes a comparison with a value of a setpoint regulation temperature of the gas Treg_set_gas.

[0117] The minimum and maximum value of the setpoint temperature of the delivery water of the heat pump 3 are variable over time and therefore define a moving band within which the Proportional-Integrative controller operates.

[0118] The Proportional-Integrative type controller is realized by means of a suitable software program executed in the control unit 10.

[0119] In one embodiment in which the heat pump 3 operates at modulated thermal power, the minimum setpoint value of the temperature of the delivery water of the heat pump 3 of the hybrid heating plant 1 is calculated with the following algorithm:

- in the case in which the heat pump 3 operates at the modulated thermal power mode for a time interval Δt greater than or equal to a threshold value (for example, equal to 45 minutes), the minimum value Tset_PdC_min of the setpoint temperature Tset_PdC of the delivery water of the heat pump 3 is equal to the difference between the maximum value Tset_PdC_max of the setpoint temperature Tset_PdC of the delivery water of the heat pump 3 and the desired temperature difference ΔT_in_out of the water between the inlet pipe 20 and the outlet pipe 21 of the heat pump 3 as shown by the dash-dotted line 211 of Figure 5A, i.e. expressed in formula with Tset_PdC_min= Tset_max_PdC- Δ in_out;
- in the case in which the heat pump 3 operates at the modulated thermal power mode for a time interval ΔT lower than the threshold value, the minimum value Tset_PdC_min of the setpoint temperature Tset_PdC of the delivery water of the heat pump 3 is equal to the maximum value Tset_PdC_max of the setpoint temperature Tset_PdC of the delivery water of the heat pump 3 at the instant in which the switching of the operation of the heat pump 3 from the maximum thermal power mode to the modulated thermal power mode occurs (see dashed line 221 of Figure 5B at instant t21), then subsequently to the switching instant the difference between the minimum value Tset_PdC_min and the maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 increases until the minimum value Tset_PdC_min reaches a value ΔT_in_out equal to the desired temperature difference of the water between the inlet and the outlet of the heat pump 3 (see dashed line 221 at the instant t22 and later).

[0120] The calculation of the minimum value of the setpoint temperature of the delivery water of the heat pump 3 is carried out by means of a suitable software program executed by the control unit 10.

[0121] With reference to Figures 4A and 4B, they show a possible trend over time of the maximum value

Tset_PdC_max of the setpoint temperature (measured in degrees centigrade) of the delivery water of the heat pump 3 (line 202 and 202a), of the actual temperature Tm_PdC of the delivery water of the heat pump 3 (line 201) and of the actual temperature of the return water Tr_w of the heat exchanger 5 (line 203), when the heat pump 3 operates at the maximum thermal power mode.

[0122] It can be noted in Figures 4A-4B that the maximum value Tset_PdC_max (indicated with a solid line with reference numbers 202 and 202a) of the setpoint temperature of the delivery water of the heat pump 3 has a variable trend over time comprised between 45-46 degrees centigrade and 52-53 degrees centigrade.

[0123] It is also possible to note in Figure 4B that the trend of the actual temperature Tm_PdC of the delivery water of the heat pump 3 (indicated with a dashed line with the reference number 201) is also variable over time and is oscillating with values comprised between 45 and 53 degrees centigrade.

[0124] Furthermore, the trend of the actual temperature Tm_PdC of the delivery water of the heat pump 3 chases the trend of the maximum value Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 as the time varies, except for small differences in values which are caused by the instability of the temperature of the return water Tr_w of the heat exchanger 5.

[0125] It can be noted in Figure 4B that also the actual temperature of the return water Tr_w (indicated with a dash-dotted line with the reference number 203) of the heat exchanger 5 has a variable trend over time and is oscillating with values comprised between 39 and 46 degrees centigrade.

[0126] Furthermore, the actual temperature of the return water Tr_w of the heat exchanger 5 has an oscillating trend similar to the oscillating trend of the actual temperature Tm_PdC of the delivery water of the heat pump 3, wherein the values of the actual temperature of the return water Tr_w are always lower than the corresponding values of the actual temperature Tm_PdC of the delivery water.

[0127] With reference to Figure 5A, a first possible trend of the setpoint temperature T_set_PdC of the delivery water of the heat pump 3 (line 210), of the minimum value Tset_PdC_min (line 211) of the setpoint temperature of the delivery water of the heat pump 3 and of the maximum value Tset_PdC_max (line 212) of the setpoint temperature of the delivery water of the heat pump 3 is shown, when this operates at the modulated thermal power mode.

[0128] It can be noted in Figure 5A that the values of the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 (line 210) when the time varies at each instant are comprised (at the equal limit) between the respective minimum values Tset_PdC_min (line 211) and maximum values Tset_PdC_max (line 212) of the setpoint temperature of the delivery water of the heat pump 3, wherein said minimum values Tset_PdC_min and maximum values Tset_PdC_max of the setpoint temperature of the delivery water of the heat pump 3 vary dynamically over time, as illustrated above.

[0129] For example, Figure 5A shows that at instant t10 the value of the setpoint temperature of the delivery water Tset_PdC of the heat pump 3 is equal to 42 degrees centigrade, which is comprised between the minimum value of the setpoint temperature equal to 35 degrees centigrade and the maximum value of the setpoint temperature equal to 49 degrees centigrade.

[0130] It can also be noted that there are two time intervals:

- a first time interval comprised between the initial instant t0 and the instant t11, in which the trend of the maximum value Tset_PdC_max is equal to the sum of the trend of the minimum value Tset_PdC_min and of a first value ΔT1_in_out equal to the desired temperature difference of the water between the inlet and the outlet of the heat pump 3;
- a second time interval subsequent to the instant t11, in which the trend of the maximum value Tset_PdC_max is equal to the sum of the trend of the minimum value Tset_PdC_min and of a second value ΔT2_in_out equal to the desired temperature difference of the water between the inlet and the outlet of the heat pump 3, in which ΔT2_in_out is lower than ΔT1_in_out.

[0131] With reference to Figure 5B, a second possible trend of the minimum value Tset_PdC_min (line 221) of the setpoint temperature of the delivery water of the heat pump 3 and of the maximum value Tset_PdC_max (line 222) of the setpoint temperature of the delivery water of the heat pump 3 is shown, when this switches from the operation at maximum thermal power to the operation at modulated thermal power and subsequently operates at modulated thermal power mode.

[0132] It can also be noted in Figure 5B that the minimum values Tset_PdC_min (line 221) and maximum values Tset_PdC_max (line 222) of the setpoint temperature of the delivery water of the heat pump 3 vary dynamically over time.

[0133] It can also be noted that there are two time intervals:

- a first time interval comprised between the initial instant t20 and the instant t22, in which the heat pump 3 operates at the maximum thermal power mode;
- a second time interval subsequent to the instant t22, in which the heat pump 3 operates at the modulated thermal power mode.

[0134] Therefore at instant t21 the heat pump 3 switches from the maximum thermal power operating mode to the modulated thermal power operating mode and at switching instant t21 the minimum value Tset_PdC_min of the setpoint temperature Tset_PdC of the delivery water of the heat pump 3 is equal to the maximum value Tset_PdC_max of the setpoint temperature Tset_PdC of the delivery water of the heat pump 3.

[0135] Subsequently to the switching instant t21, it can be noted that the minimum value Tset_PdC_min (line 221) of the setpoint temperature of the delivery water of the heat pump 3 gradually decreases, until at instant t22 the minimum value Tset_PdC_min is equal to the difference between the maximum value Tset_PdC_max (line 222) of the setpoint temperature of the delivery water of the heat pump 3 and the desired temperature difference ΔT_in_out of the water between the inlet and the outlet of the heat pump: therefore at the instants subsequent to t22 the trend of the maximum value Tset_PdC_max (line 222) is equal to the sum of the trend of the minimum value Tset_PdC_min (line 221) and of the value ΔT_in_out of the desired temperature difference of the water between the inlet and the outlet of the heat pump 3.

Claims

1. Method (100) for controlling the setpoint temperature (Tset_PdC) of the delivery water of a heat pump (3) of a hybrid heating plant (1) comprising a gas boiler (4) operating in combination with the heat pump to heat a gas by means of a heat exchanger (5), the method comprising the steps of:

    a) acquiring (102) at a time instant values indicative of the temperature of the return water (Tr_w) of the heat exchanger (5), of the temperature of the gas (T_gas), of the flow rate of the water (Fm_o_PdC) associated with the heat pump, of the operating state of the heat pump and of the operating state of the gas boiler;
    b) detecting a switched on or off operating state of the gas boiler within a defined time interval preceding said time instant;
    c) checking (103) whether the heat pump is active or inactive;
    d) detecting that the heat pump is active and comparing (104) the value of said temperature of the gas (T_gas) with respect to a setpoint temperature value of the gas (T1_set_gas);
    e) detecting that the value of the temperature of the gas (T_gas) is lower than the setpoint temperature value of the gas (T1_set_gas) and checking (106) whether the gas boiler is always switched off in a defined time interval preceding said time instant;
    f) in the case (106) in which the gas boiler is not always switched off in said defined time interval, calculating (108) a maximum value of the setpoint temperature of the delivery water (Tset_PdC) of the heat pump (3) as a function of the temperature of the return water (Tr_w) of the heat exchanger and of the flow rate of the water (Fm_o_PdC) associated with the heat pump and setting said calculated maximum value for the setpoint temperature of the delivery water (Tset_PdC) of the heat pump, so that the heat pump operates at a maximum thermal power mode;
    g) in the case (106) in which the gas boiler is always switched off in said defined time interval, changing (109) the value of the setpoint temperature of the delivery water of the heat pump between a minimum value and said calculated maximum value of the setpoint temperature, so that the heat pump operates at a modulated thermal power mode.

2. Method according to claim 1, further comprising, after step c), the steps of:

    d1) detecting that the heat pump is inactive and comparing (105) the value of the temperature of the gas (T_gas) with respect to a further setpoint temperature value of the gas (T2_set_gas), wherein said further setpoint temperature value of the gas (T2_set_gas) is lower than said setpoint temperature value of the gas (T1_set_gas);
    e1) detecting that the value of the temperature of the gas (T_gas) is lower than the further setpoint temperature value of the gas (T2_set_gas) and checking (106) whether the gas boiler is always switched off in said defined time interval;
    f1) in the case in which the gas boiler is not always switched off in said defined time interval, calculating (108) a maximum value of the setpoint temperature of the delivery water (Tset_PdC) of the heat pump as a function of the temperature of the return water (Tr_w) of the heat exchanger and of the flow rate of the water (Fm_o_PdC) associated with the heat pump and setting said calculated maximum value for the setpoint temperature of the delivery water (Tset_PdC) of the heat pump;
    g1) in the case in which the gas boiler is always switched off in said defined time interval, varying (109) the value of the setpoint temperature of the delivery water of the heat pump between said minimum value and said calculated maximum value of the setpoint temperature, so that the heat pump operates at a modulated thermal power mode.

3. Method according to claims 1 or 2, further comprising, after step c), the steps of:

    d2) detecting (103) that the heat pump is active and detecting (104) that the value of the temperature of the gas (T_gas) is greater than the setpoint temperature value of the gas

(T1_set_gas) and checking (107) whether the gas boiler is always switched off in said defined time interval;

e2) in the case in which the gas boiler is always switched off in said defined time interval, setting (111) the value of the setpoint temperature of the delivery water of the heat pump so that it is switched off;

f2) in the case in which the gas boiler is not always switched off in said defined time interval, setting (110) the value of the setpoint temperature of the delivery water of the heat pump so that it is in a stand-by state.

4. Method according to claim 2 or according to claim 3 when depending on 2, further comprising, after step c1), the steps of:

d2) detecting (103) that the heat pump is inactive and detecting (105) that the value of the temperature of the gas (T_gas) is greater than said further setpoint temperature value of the gas (T2_set_gas) and checking (107) whether the gas boiler is always switched off in said defined time interval;

e3) in the case in which the gas boiler is always switched off in said defined time interval, setting (111) the value of the setpoint temperature of the delivery water of the heat pump so that it is switched off;

f3) in the case in which the gas boiler is not always switched off in said defined time interval, setting (110) the value of the setpoint temperature of the delivery water of the heat pump so that it is in a stand-by state.

5. Method according to any one of the preceding claims, wherein in step f) or f1) or g) the maximum value of the setpoint temperature of the delivery water of the heat pump is calculated as follows:

- calculating (152) a plurality of values of a statistical index of the temperature of the return water (Tr_w) of the heat exchanger in a respective plurality of defined time intervals preceding said time instant, in particular the statistical index is an average value of the temperature of the return water (Tr_w) of the heat exchanger;
- detecting (153) that the current value of the temperature of the return water of the heat exchanger is lower than a value of a setpoint temperature of the return water of the heat exchanger;
- analysing (154) the trend of the plurality of calculated values of the statistical index of the temperature of the return water (Tr_w) of the heat exchanger;
- in the case in which said trend is increasing in said plurality of time intervals, keeping the maximum value of the setpoint temperature of the delivery water of the heat pump unchanged (158);
- in the case in which said trend is decreasing in said plurality of time intervals, decreasing (156) the maximum value of the setpoint temperature of the delivery water of the heat pump and decreasing the value of the setpoint temperature of the return water as a function of the objective power of the heat pump and of the flow rate of the water (Fm_o_PdC) associated with the heat pump, or as a function of a desired temperature difference of the fluid between inlet and outlet of the heat pump.

6. Method according to claim 5, further comprising:

- detecting (153) that the value of the temperature of the return water of the heat exchanger is greater than or equal to the value of the setpoint temperature of the return water of the heat exchanger;
- analysing (155) the trend of the plurality of calculated values of the statistical index of the temperature of the return water (Tr_w) of the heat exchanger;
- in the case in which said trend is decreasing in said plurality of time intervals, keeping the maximum value of the setpoint temperature of the delivery water of the heat pump unchanged (158);
- in the case in which said trend is increasing in said plurality of time intervals, increasing (157) the maximum value of the setpoint temperature of the delivery water of the heat pump and increasing the value of the setpoint temperature of the return water as a function of the objective power of the heat pump and of the flow rate of the water (Fm_o_PdC) associated with the heat pump, or as a function of the desired temperature difference of the fluid between inlet and outlet of the heat pump.

7. Method according to any one of the preceding claims, wherein in step g) the minimum value of the setpoint temperature of the delivery water of the heat pump comprises:

- in the case in which the heat pump operates at the modulated thermal power mode for a time interval greater than or equal to a threshold value, setting the minimum value of the setpoint temperature of the delivery water of the heat pump equal to the difference between the maximum value of the setpoint temperature of the delivery water of the heat pump (3) and the desired temperature difference of the fluid between

the inlet and the outlet of the heat pump;
- in the case in which the heat pump (3) operates at the modulated thermal power mode for a time interval lower than the threshold value, setting the minimum value of the setpoint temperature of the delivery water of the heat pump equal to the maximum value of the setpoint temperature of the delivery water of the heat pump at the instant in which a switching of the operation of the heat pump from the maximum thermal power mode to the modulated thermal power mode occurs, and gradually decreasing the minimum value of the setpoint temperature of the delivery water of the heat pump until the minimum value is equal to the difference between the maximum value of the setpoint temperature of the delivery water of the heat pump and the desired temperature difference (ΔT_out_) of the water between the inlet and the outlet of the heat pump.

8. Method according to claim 7, wherein in step g) the value of the setpoint temperature of the delivery water of the heat pump varies between the minimum value and the maximum value by means of a Proportional-Integrative control that receives the value of the temperature of the gas (T_gas) in input and makes a comparison with a value of a gas regulation setpoint temperature.

9. Method according to any one of the preceding claims, wherein the temperature of the gas is the temperature of the heated gas measured at the outlet from the heat exchanger or is the temperature of the decompressed gas measured at the outlet from a pressure regulator (15).

10. Method according to any one of the preceding claims, wherein step a) further comprises acquiring values indicative of the temperature of the delivery water of the gas boiler (T_o_c),
and wherein in step b) the operating state of the boiler is calculated as a function of a comparison between a difference between the temperature of the delivery water of the gas boiler (T_o_c) and the temperature of the return water (Tr_w) of the heat exchanger (5) and an activation temperature threshold value.

11. Non-transitory computer-readable storage medium comprising instructions which, when executed on a computer, cause the computer to carry out the steps of the method according to claims 1-9.

12. Hybrid heating plant (1) for heating a gas, the plant comprising a gas boiler (4), a heat pump (3) operating in combination with the gas boiler, a heat exchanger (5) to heat the gas and a control unit (10) electrically connected to the heat pump and with the gas boiler,
the plant further comprising a first sensor (8) electrically connected to the control unit and configured to detect a value indicative of a temperature of the return water (Tr_w) of the heat exchanger, a second sensor (6) electrically connected to the control unit and configured to generate a value indicative of the temperature of the decompressed gas (T_gas) or of the gas past the heat exchanger and a third sensor (19) electrically connected to the control unit and configured to generate a value indicative of the flow rate of the water (Fm_o_PdC) associated with the heat pump,
wherein the control unit is configured to:

- acquire at a time instant values indicative of the temperature of the return water (Tr_w) of the heat exchanger, of the temperature of the gas (T_gas), of the flow rate of the water (Fm_o_PdC) associated with the heat pump, of the operating state of the heat pump and of the operating state of the gas boiler;
- detect a switched on or off operating state of the gas boiler within a defined time interval preceding said time instant;
- check whether the heat pump is active or inactive;
- detect that the heat pump is active and compare the value of said temperature of the gas (T_gas) with respect to a setpoint temperature value of the gas (T1_set_gas);
- detect that the value of the temperature of the gas (T_gas) is lower than the setpoint temperature value of the gas (T1_set_gas) and check whether the gas boiler is always switched off in a defined time interval preceding said time instant;
- in the case in which the gas boiler is not always switched off in a defined time interval preceding said time instant, calculate a maximum value of the setpoint temperature of the delivery water of the heat pump as a function of the temperature of the return water (Tr_w) of the heat exchanger and of the flow rate of the water (Fm_o_PdC) associated with the heat pump and generate a control signal of the heat pump (Tset_PdC) to set said calculated maximum value for the setpoint temperature of the delivery water of the heat pump, so that the heat pump operates at a maximum thermal power mode;
- in the case in which the gas boiler is always switched off in the defined time interval preceding said time instant, generating the control signal (Tset_PdC) of the heat pump to vary the value of the setpoint temperature

of the delivery water of the heat pump between a minimum value and said calculated maximum value of the setpoint temperature, so that the heat pump operates at a modulated thermal power mode.

13. Hybrid heating plant (1) according to claim 12, wherein the control unit is further configured to:

- detect that the heat pump is inactive and compare the value of the temperature of the gas (T_gas) with respect to a further setpoint temperature value of the gas (T2_set_gas);
- detect that the value of the temperature of the gas (T_gas) is lower than the second setpoint temperature value of the gas (T2_set_gas) and check whether the gas boiler is always switched off in said defined time interval preceding said current time instant;
- in the case in which the gas boiler is not always switched off in the defined time interval preceding said time instant, calculate (108) a maximum value of the setpoint temperature of the delivery water of the heat pump as a function of the temperature of the return water (Tr_w) of the heat exchanger and the flow rate of the water (Fm_o_PdC) associated with the heat pump and generate the control signal (Tset_PdC) of the heat pump to set said calculated maximum value;
- in the case in which the gas boiler is always switched off in the defined time interval preceding said time instant, generate the control signal (Tset_PdC) of the heat pump to change the value of the setpoint temperature of the delivery water of the heat pump between said minimum value and said calculated maximum value of the setpoint temperature, so that the heat pump operates at a modulated thermal power mode.

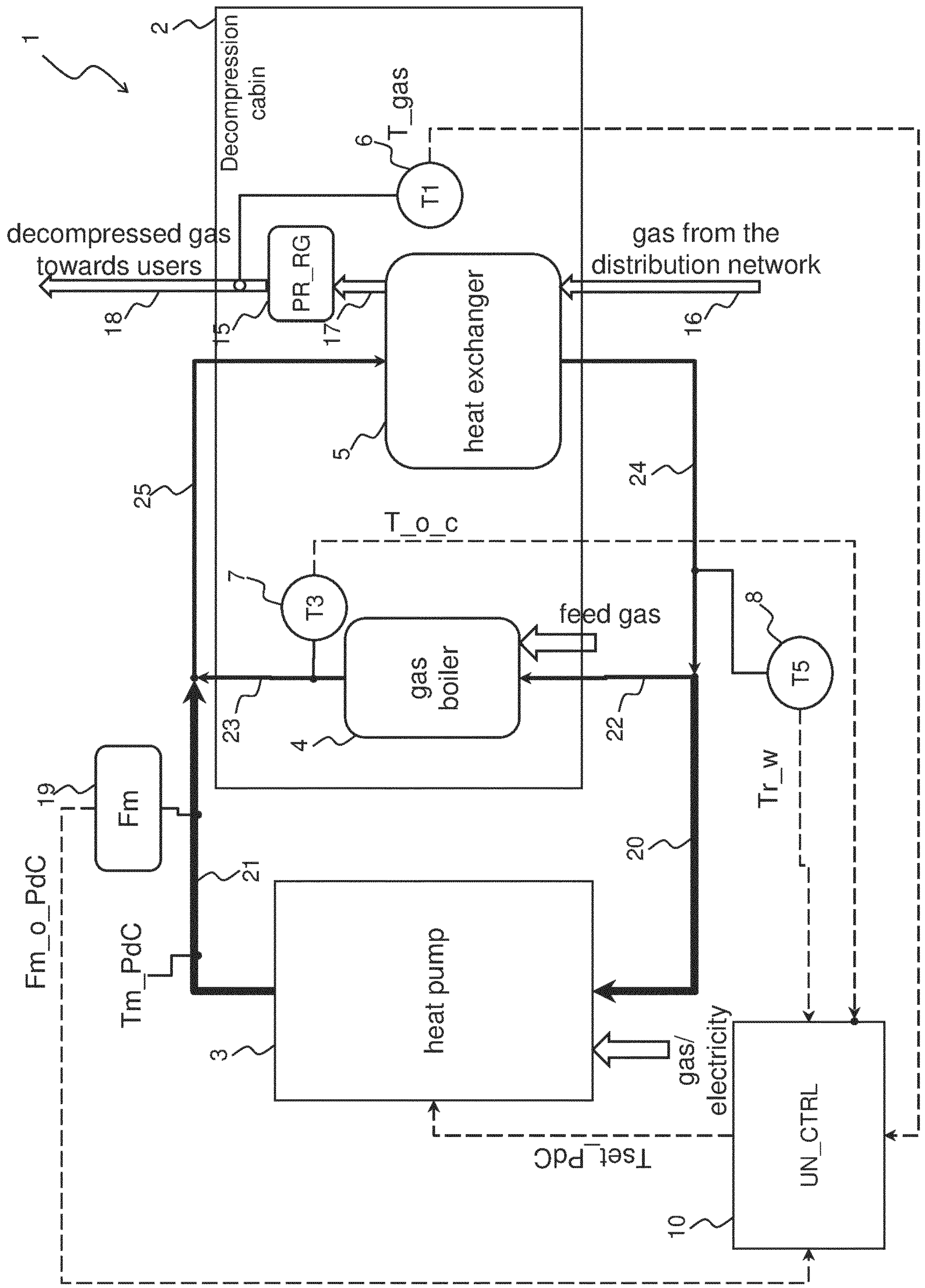

1
2
Decompression cabin
6
T_gas
T1
PR_RG
decompressed gas towards users
gas from the distribution network
18
15
17
16
heat exchanger
5
25
24
T_o_c
7
T3
8
feed gas
T5
gas boiler
4
23
22
Tr_w
19
Fm
Fm_o_PdC
21
20
Tm_PdC
heat pump
3
gas/ electricity
UN_CTRL
Tset_PdC
10

Fig. 1

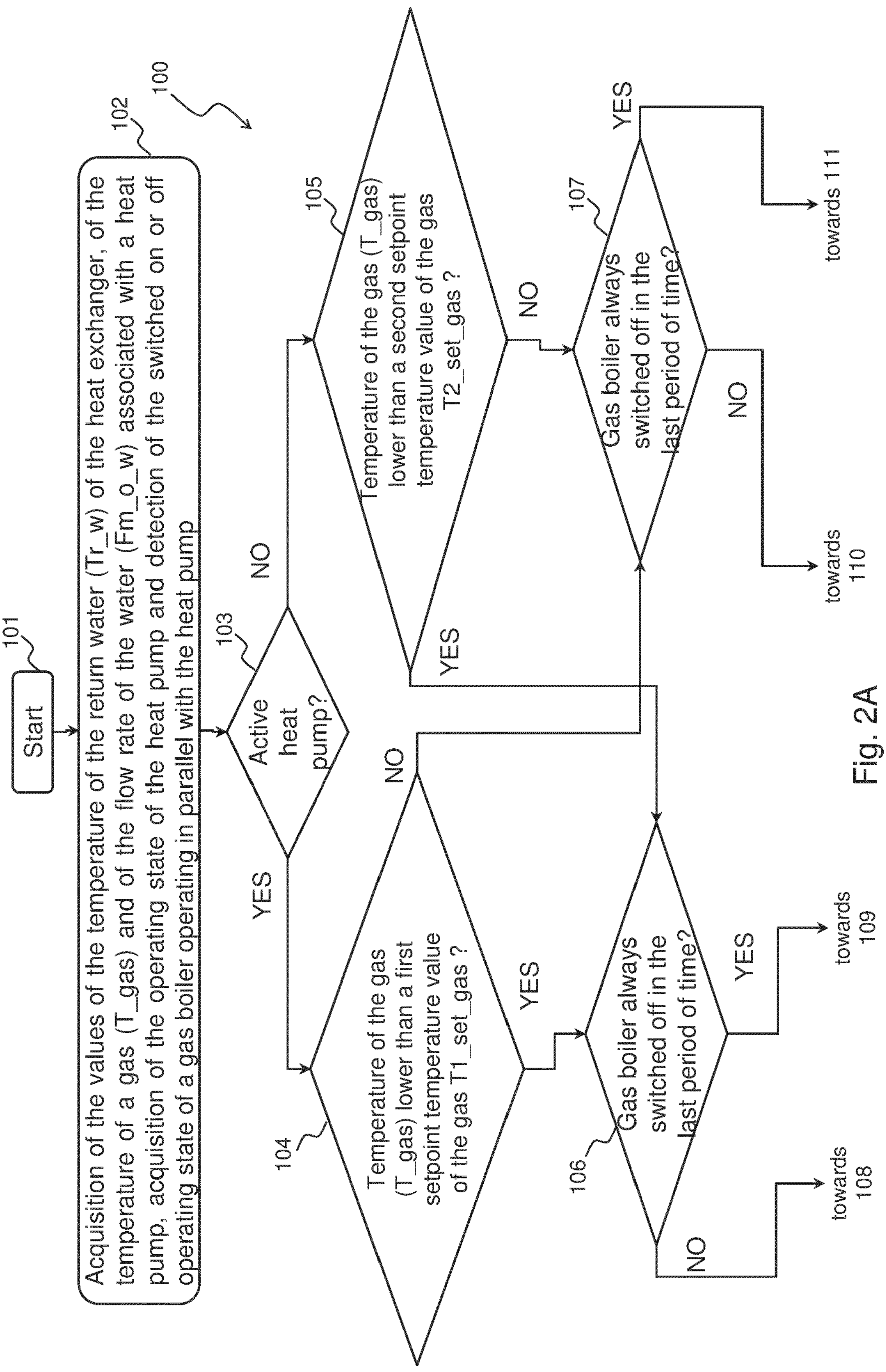

100
Start
101
Acquisition of the values of the temperature of the return water (Tr_w) of the heat exchanger, of the temperature of a gas (T_gas) and of the flow rate of the water (Fm_o_w) associated with a heat pump, acquisition of the operating state of the heat pump and detection of the switched on or off operating state of a gas boiler operating in parallel with the heat pump
102
Active heat pump?
103
YES
NO
Temperature of the gas (T_gas) lower than a first setpoint temperature value of the gas T1_set_gas ?
104
Temperature of the gas (T_gas) lower than a second setpoint temperature value of the gas T2_set_gas ?
105
YES
NO
YES
NO
Gas boiler always switched off in the last period of time?
106
Gas boiler always switched off in the last period of time?
107
NO
YES
NO
YES
towards 108
towards 109
towards 110
towards 111

Fig. 2A

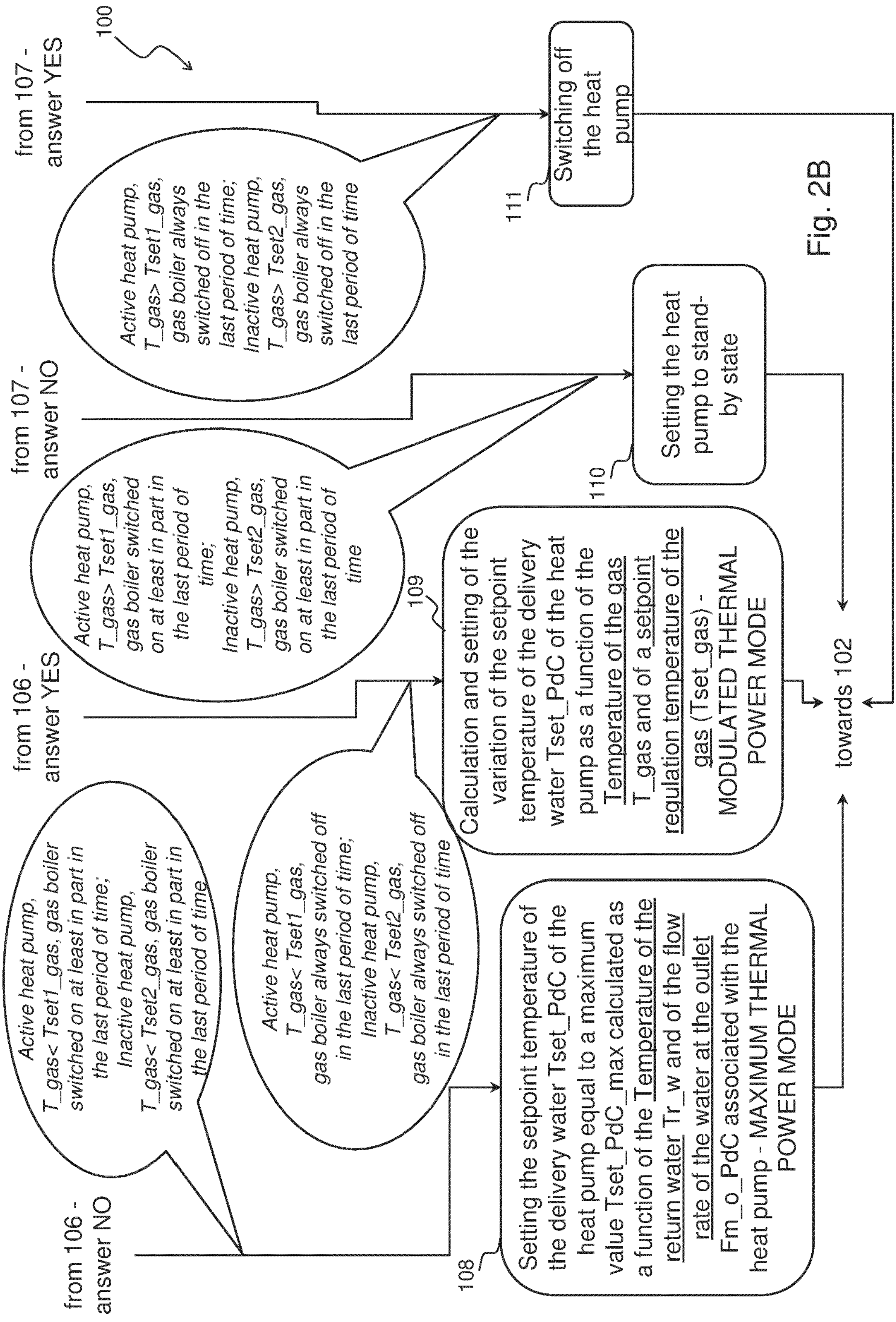

100
from 107 - answer YES
from 107 - answer NO
from 106 - answer YES
from 106 - answer NO
Active heat pump, T_gas> Tset1_gas, gas boiler always switched off in the last period of time; Inactive heat pump, T_gas> Tset2_gas, gas boiler always switched off in the last period of time
Active heat pump, T_gas> Tset1_gas, gas boiler switched on at least in part in the last period of time; Inactive heat pump, T_gas> Tset2_gas, gas boiler switched on at least in part in the last period of time
Active heat pump, T_gas< Tset1_gas, gas boiler switched on at least in part in the last period of time; Inactive heat pump, T_gas< Tset2_gas, gas boiler switched on at least in part in the last period of time
Active heat pump, T_gas< Tset1_gas, gas boiler always switched off in the last period of time; Inactive heat pump, T_gas< Tset2_gas, gas boiler always switched off in the last period of time
111
Switching off the heat pump
110
Setting the heat pump to stand-by state
109
Calculation and setting of the variation of the setpoint temperature of the delivery water Tset_PdC of the heat pump as a function of the Temperature of the gas T_gas and of a setpoint regulation temperature of the gas (Tset_gas) - MODULATED THERMAL POWER MODE
108
Setting the setpoint temperature of the delivery water Tset_PdC of the heat pump equal to a maximum value Tset_PdC_max calculated as a function of the Temperature of the return water Tr_w and of the flow rate of the water at the outlet Fm_o_PdC associated with the heat pump - MAXIMUM THERMAL POWER MODE
towards 102

Fig. 2B

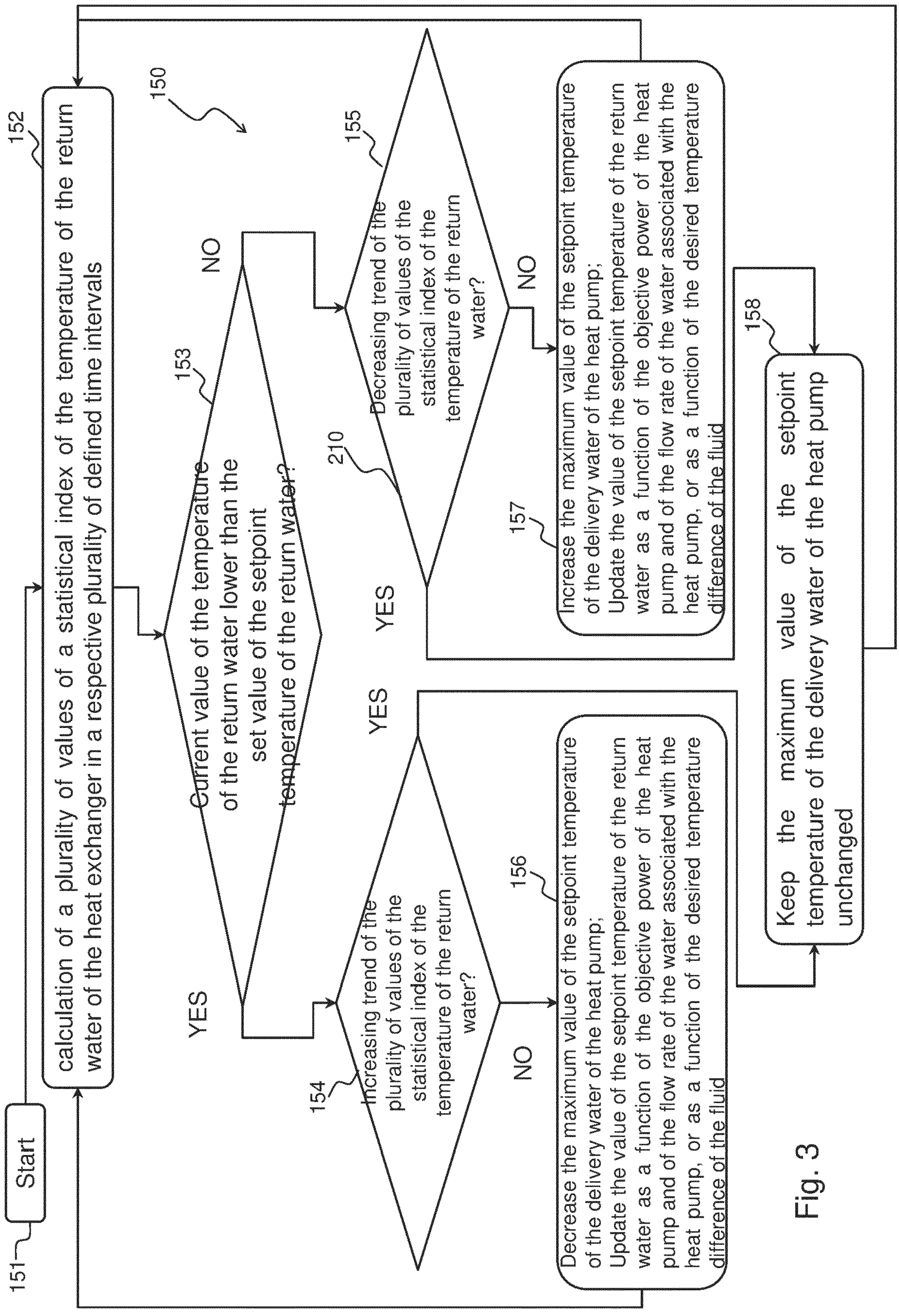

Start
151
152
calculation of a plurality of values of a statistical index of the temperature of the return water of the heat exchanger in a respective plurality of defined time intervals
150
153
Current value of the temperature of the return water lower than the set value of the setpoint temperature of the return water?
YES
NO
154
Increasing trend of the plurality of values of the statistical index of the temperature of the return water?
155
Decreasing trend of the plurality of values of the statistical index of the temperature of the return water?
210
YES
NO
YES
NO
156
Decrease the maximum value of the setpoint temperature of the delivery water of the heat pump;
Update the value of the setpoint temperature of the return water as a function of the objective power of the heat pump and of the flow rate of the water associated with the heat pump, or as a function of the desired temperature difference of the fluid
157
Increase the maximum value of the setpoint temperature of the delivery water of the heat pump;
Update the value of the setpoint temperature of the return water as a function of the objective power of the heat pump and of the flow rate of the water associated with the heat pump, or as a function of the desired temperature difference of the fluid
158
Keep the maximum value of the setpoint temperature of the delivery water of the heat pump unchanged

Fig. 3

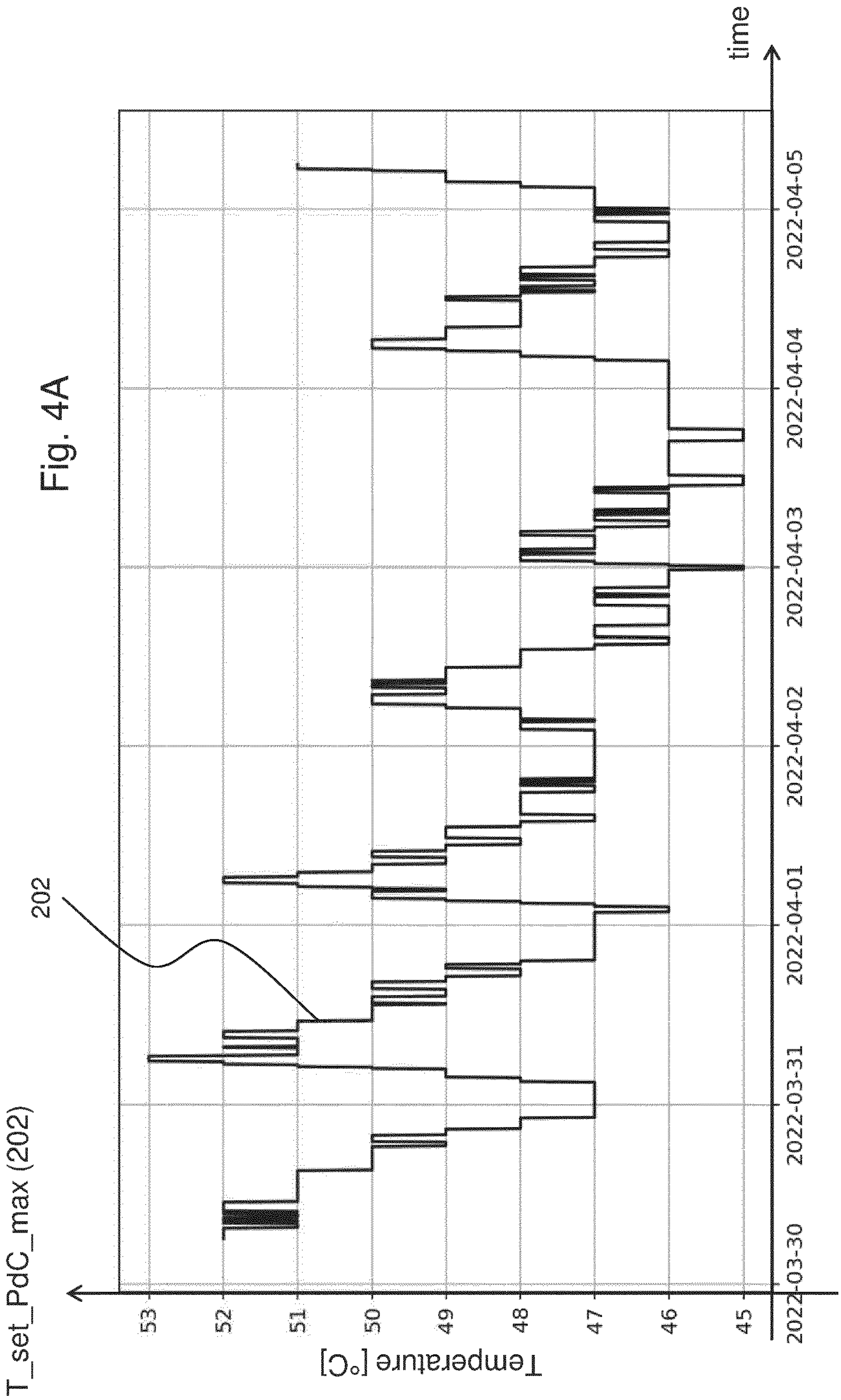

T_set_PdC_max (202)
202
time
Temperature [°C]
53
52
51
50
49
48
47
46
45
2022-03-30
2022-03-31
2022-04-01
2022-04-02
2022-04-03
2022-04-04
2022-04-05

Fig. 4A

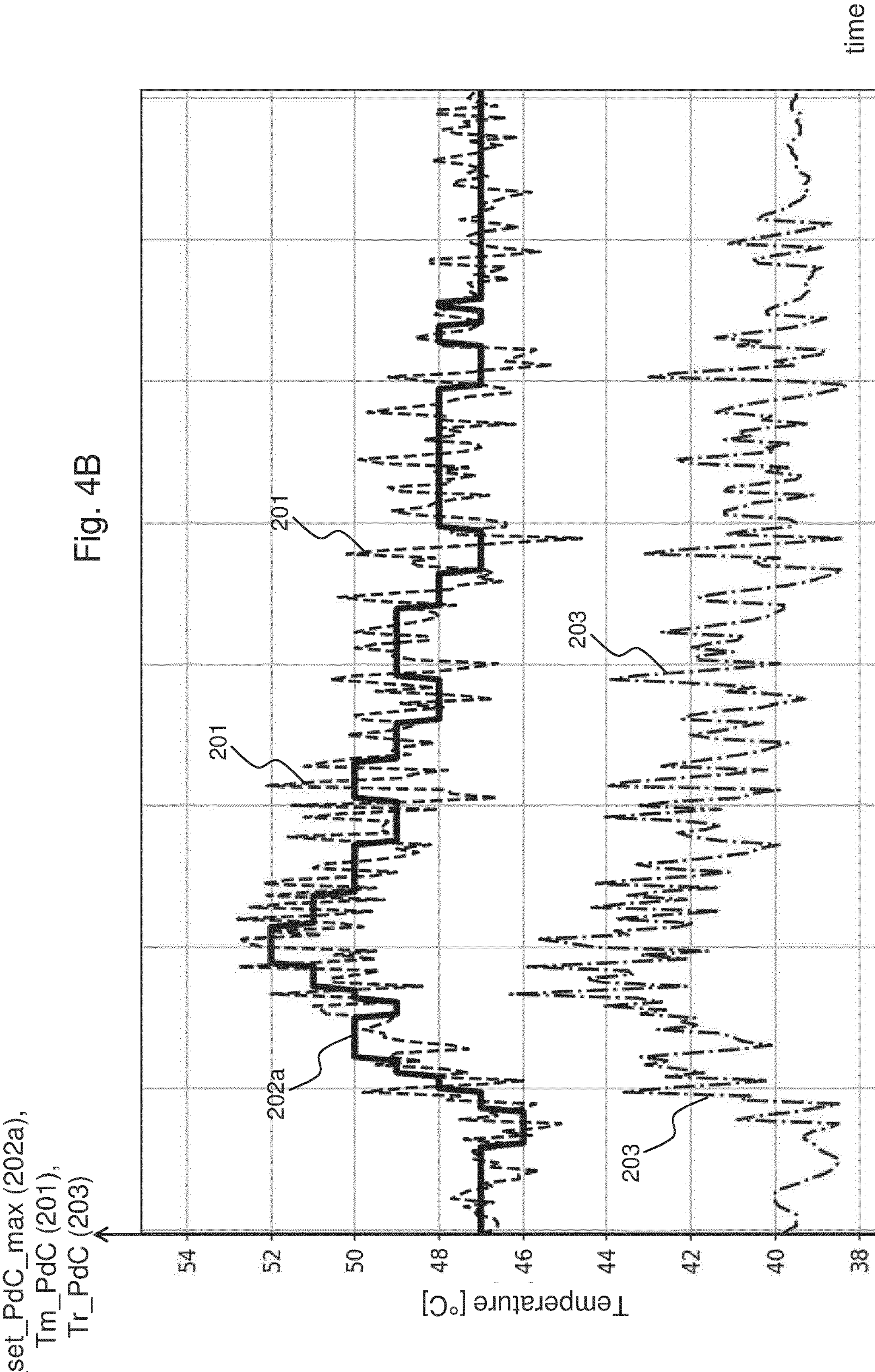
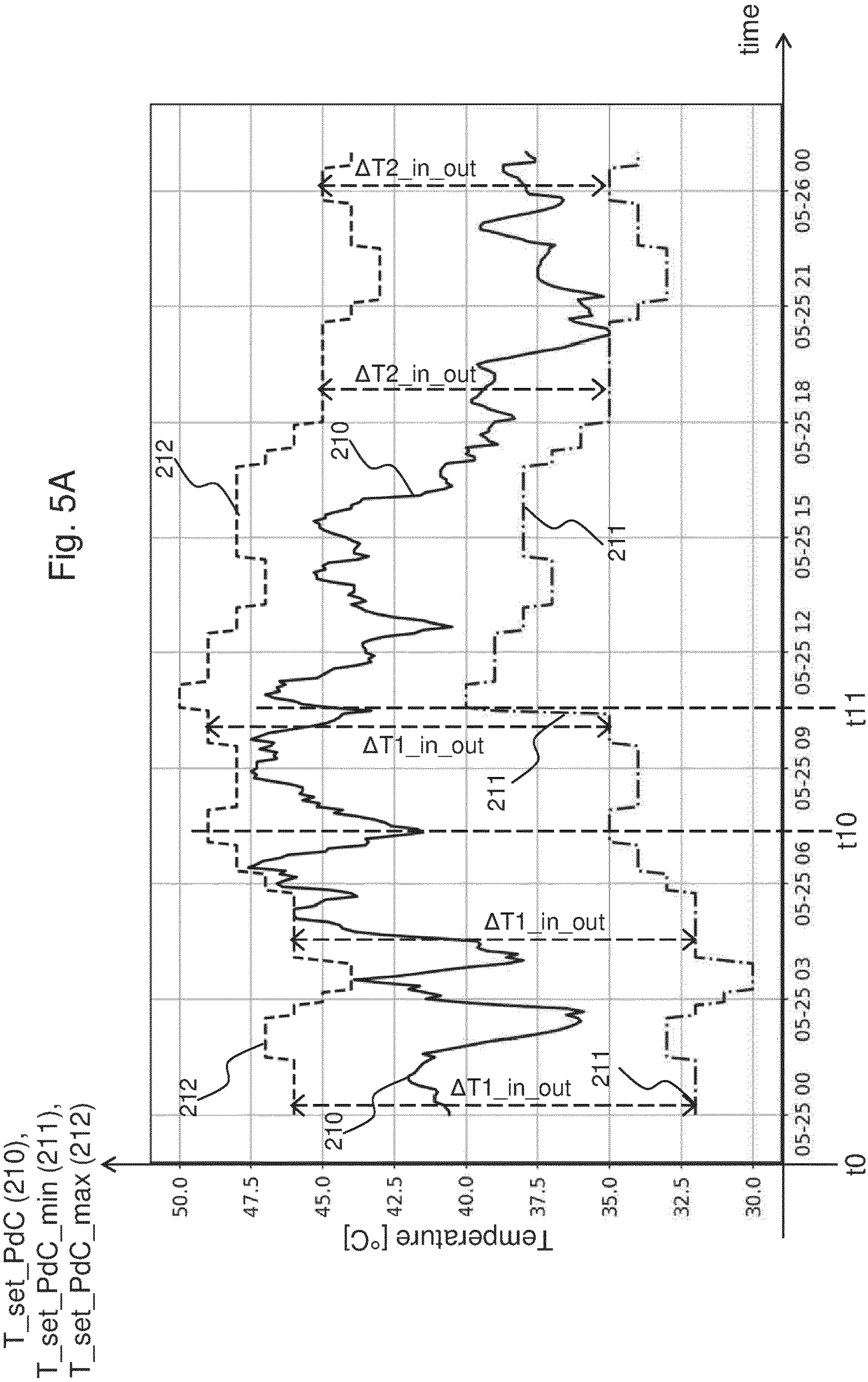

T_set_PdC_max (202a),
Tm_PdC (201),
Tr_PdC (203)
Temperature [°C]
54
52
50
48
46
44
42
40
38
time
04-01 00
04-01 03
04-01 06
04-01 09
04-01 12
04-01 15
04-01 18
04-01 21
04-02 00
201
201
202a
203
203

Fig. 4B

Fig. 5A


T_set_PdC (210),
T_set_PdC_min (211),
T_set_PdC_max (212)
Temperature [°C]
50.0
47.5
45.0
42.5
40.0
37.5
35.0
32.5
30.0
05-25 00
05-25 03
05-25 06
05-25 09
05-25 12
05-25 15
05-25 18
05-25 21
05-26 00
time
t0
t10
t11
ΔT1_in_out
ΔT1_in_out
ΔT1_in_out
ΔT2_in_out
ΔT2_in_out
210
211
212
210
211
212
211

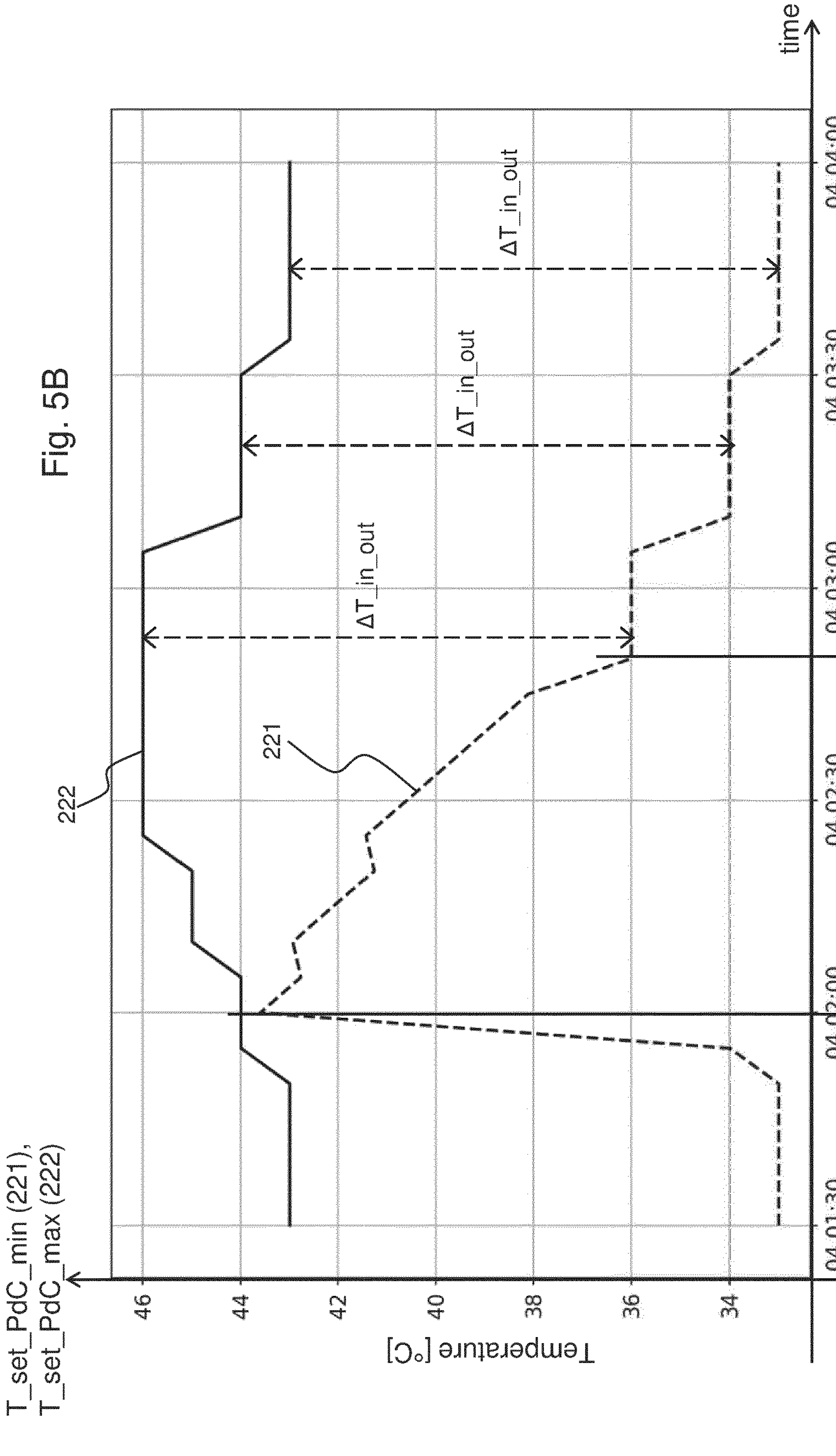

T_set_PdC_min (221),
T_set_PdC_max (222)
Temperature [°C]
46
44
42
40
38
36
34
t20
04 01:30
04 02:00
t21
04 02:30
04 03:00
t22
04 03:30
04 04:00
time
222
221
ΔT_in_out
ΔT_in_out
ΔT_in_out

Fig. 5B

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EUROPEAN SEARCH REPORT

Application Number
EP 23 42 5004

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	9 June 2023	Schwaiger, Bernd

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