(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 961 127 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.03.2022 Bulletin 2022/09

(21) Application number: **20193681.2**

(22) Date of filing: **31.08.2020**

(51) International Patent Classification (IPC):
F25B 25/00 *(2006.01)* ***F25B 49/02*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F25B 25/005; F25B 49/02; F25B 2600/2501

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicants:
- **Mitsubishi Electric R&D Centre Europe B.V.**
  Livingston EH54 5DJ (GB)
  Designated Contracting States:
  GB
- **Mitsubishi Electric Corporation**
  Tokyo 100-8310 (JP)
  Designated Contracting States:
  AL AT BE BG CH CY CZ DE DK EE ES FI FR GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(72) Inventors:
- **WU, Duan**
  Livingston, EH54 5DJ (GB)
- **KAWALEY, Georgeanna**
  Livingston, EH54 5DJ (GB)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

(54) AIR CONDITIONING SYSTEM AND METHOD FOR ITS CONTROL

(57) An air conditioning system and a method for its control is provided. The air conditioning system comprises a heating and/or cooling part and a heat transfer circuit, wherein a first heat exchanger thermally connects the heating and/or cooling part with the heat transfer circuit. The heat transfer circuit comprises a pump configured to circulate a heat transfer medium in the heat transfer circuit, a second heat exchanger configured to transfer heat between the heat transfer medium of the heat transfer circuit and an indoor space, and a bypass line bypassing the second heat exchanger, wherein the bypass line comprises a bypass valve between a first and a second end of the bypass line, wherein the bypass valve is configured to control a flow through the bypass line and wherein the heat transfer circuit comprises a heat transfer medium containing a phase change material. A controller of the system is configured to control an opening degree of the bypass valve. The presented air conditioning system has an increased coefficient of performance.

EP 3 961 127 A1

Description

[0001] An air conditioning system and a method for its control is provided. The air conditioning system comprises a heating and/or cooling part and a heat transfer circuit, wherein a first heat exchanger thermally connects the heating and/or cooling part with the heat transfer circuit. The heat transfer circuit comprises a pump configured to circulate a heat transfer medium in the heat transfer circuit, a second heat exchanger configured to transfer heat between the heat transfer medium of the heat transfer circuit and an indoor space, and a bypass line bypassing the second heat exchanger, wherein the bypass line comprises a bypass valve between a first and a second end of the bypass line, wherein the bypass valve is configured to control a flow through the bypass line and wherein the heat transfer circuit comprises a heat transfer medium containing a phase change material. A controller of the system is configured to control an opening degree of the bypass valve. The presented air conditioning system has an increased coefficient of performance.

[0002] In conventional HVAC systems, water or refrigerant is used for transport heating or cooling to indoor unit for maintaining the indoor temperature or comfort. A slurry of a phase change material (PCM slurry) can be used to reduce the usage of refrigerant due to increased F-gas regulation to reduce greenhouse gas emission.

[0003] The main challenge for PCM slurry based systems to control the system operation is to guarantee the operation temperature range is suitable for specific PCM material and concentration as well as to deliver the correct amount of cooling capacity to the indoor space.

[0004] For a PCM slurry based system, the degree of freedom of the system is increased due to the phase change temperature variable which is related to the concentration of PCM. However, the problem with the prior art systems and methods is that the temperature of the medium containing a phase change material (PCM) cannot be controlled satisfactorily to be in the desired range around the phase change temperature of the PCM. Thus, in prior art systems and methods, the cooling capacity at an indoor unit can vary and a desired higher cooling capacity can often only be achieved by increasing the flow rate of the medium containing the PCM to very high flow rates, which consumes much electrical energy. Thus, there is a desire in the prior art to improve the coefficient of performance (COP) regarding these air conditioning systems and methods for controlling these air conditioning systems.

[0005] CN 104 673 191 A discloses a tetrabutylammonium bromide (TBAB) aqueous solution which is in heat exchange with the refrigerant and uses a cooled refrigerant to obtain a TBAB aqueous solution containing a TBAB hydrate slurry, wherein concentration of solid TBAB in the TBAB hydrate slurry and that of dissolved TBAB in the TBAB aqueous solution is the same.

[0006] US 6,237,346 B1 discloses a method for transporting cold latent-heat which is characterized in that a cold transporting medium for use in the method is a semi-clathrate hydrate (liquid-liquid clathrate) capable of crystallization when an onium salt having C_4H_9-group and iso-C_5H_{11}-group is included as a guest into basket-like clathrate lattices consisting of water molecules.

[0007] US 2017/0307263 A1 discloses a heat transfer system that includes a heat exchanger comprising an inlet, an outlet, and a flow path through the heat exchanger between the inlet and the outlet, wherein the system also includes a fluid circulation loop external to the heat exchanger connecting the outlet to the inlet, wherein a phase change composition is disposed in the system flowing through the fluid circulation loop and the flow path through the heat exchanger.

[0008] Starting from this prior art, it was the object of the present application to provide an air conditioning system and a method for controlling an air conditioning system which does not suffer the disadvantages of the prior art. Specifically, the system and method should be characterized by an increased COP compared to known systems and methods.

[0009] The object is solved by the air conditioning system according to claim 1 and the method for controlling an air conditioning system according to claim 11. The dependent claims illustrate advantageous embodiments of the invention.

[0010] According to the invention, an air conditioning system is provided which comprises

a heating and/or cooling part comprising a first part of a first heat exchanger, wherein the first heat exchanger comprises the first part and a second part and is configured to exchange heat between the first and second part, a heat transfer circuit comprising the second part of the first heat exchanger and further comprising

> a pump configured to circulate a heat transfer medium in the heat transfer circuit,
> a second heat exchanger configured to transfer heat between the heat transfer medium and an indoor space, and
> a bypass line bypassing the second heat exchanger, wherein the bypass line comprises a bypass valve between a first and a second end of the bypass line, the bypass valve being configured to control a flow through the bypass line, wherein the heat transfer circuit comprises a heat transfer medium, which is configured to be circulated in the heat transfer circuit, wherein the heat transfer medium contains a phase change material; and

a controller which is configured to control an opening degree of the bypass valve.

[0011] The advantage of the air conditioning system according to the invention is that it is has an increased coefficient of performance (COP) compared to known air conditioning systems. This advantage is achieved by the controller of the system which is configured to control an opening degree of the bypass valve. Thus, the controller can ensure that the temperature of the heat transfer medium, which comprises the phase change material (PCM), is essentially identical to the phase change temperature of the PCM, which is related to the concentration of PCM. This allows to achieve a minimum flow rate in the heat transfer circuit (slurry circuit) and energy efficiency to be improved. In comparison with a water based cooling system, the present system and method achieves a COP which is 4.5% higher which is mainly due to the pumping power reduction in the slurry circuit.

[0012] The air conditioning system can be characterized in that the heating and/or cooling part is a refrigerant circuit comprising a compressor, a condenser, an expansion device, a liquid separator and a refrigerant.

[0013] The bypass line of the system can branch off from a main circuit of the heat transfer circuit between the pump and the second heat exchanger on its first end and branches of the main circuit between the second part of the first heat exchanger and the second heat exchanger on its second end.

[0014] The heat transfer circuit can further comprise a third heat exchanger which is configured to transfer heat between the heat transfer medium and an indoor space. Furthermore, the heat transfer circuit can further comprise a storage device for storing the phase change material.

[0015] The heat transfer medium can contain the phase change material in the form of a dispersion of solid phase change material in a liquid, preferably in the form of a slurry. Furthermore, the heat transfer medium can contain the phase change material in a concentration of 5 to 20 wt.-%, preferably 7 to 15 wt.-%, more preferably 8 to 12 wt.-%, especially 10 wt.-%, relative to the total weight of the heat transfer medium. Moreover, the heat transfer medium can contain a phase change material which has a phase change temperature in the range of -5 °C to 5 °C.

[0016] The heat transfer circuit can comprise a temperature sensor at a first end of the second part of the first heat exchanger. Furthermore, the heat transfer circuit can comprise a (further) temperature sensor at a second end of the second part of the first heat exchanger. Moreover, the refrigerant circuit can comprise a temperature sensor and a pressure sensor at the discharge line of a compressor of the refrigerant circuit.

[0017] The controller can be configured to control an opening degree of an expansion device of the heating and/or cooling part based on a degree of superheat determined from a temperature sensor and a pressure sensor at the discharge line of a compressor of the refrigerant circuit. The control is preferably such that if the determined degree of superheat is higher than a predetermined value, the opening degree of the expansion device is increased and/or if the determined degree of superheat is lower than a predetermined value, the opening degree of the expansion device is decreased.

[0018] Moreover, the controller can be configured to control the speed of a compressor of the system based on the temperature of the heat transfer medium. The control is preferably such that the speed of the compressor is increased if the temperature of the phase change material is higher than the phase change temperature of the phase change material and/or the speed of the compressor is decreased if the temperature of the phase change material is lower than the phase change temperature of the phase change material. The temperature of the phase change material is preferably obtained from a temperature sensor at an inlet of the first heat exchanger.

[0019] Furthermore, the controller can be configured to control the opening degree of the bypass valve based on a differential temperature of the heat transfer medium between an inlet of the first heat exchanger and an outlet of the first heat exchanger. The control is preferably such that the opening degree of the bypass valve is increased if the differential temperature is lower than a predetermined set point and/or the opening degree of the bypass valve is decreased if the differential temperature is higher than a predetermined set point. The differential temperature is preferably calculated from a temperature obtained from a temperature sensor at an inlet of the first heat exchanger and from a temperature obtained from a temperature sensor at an outlet of the first heat exchanger.

[0020] Besides, the controller can be configured to control the conveying speed of the pump based on a cooling capacity determined from the current flow rate of the heat transfer medium and determined from a differential temperature of the heat transfer medium between an inlet of the first heat exchanger and an outlet of the first heat exchanger. The control is preferably such that the conveying speed of the pump is increased if the cooling capacity is lower than a predetermined set point and/or the conveying speed of the pump (P) is decreased if the cooling capacity is higher than a predetermined set point. The current flow of the heat transfer medium is preferably obtained from the pump and the differential temperature is preferably calculated from a temperature obtained from a temperature sensor at an inlet of the first heat exchanger and from a temperature obtained from a temperature sensor at an outlet of the first heat exchanger.

[0021] According to the invention, a method is provided for controlling an air conditioning system according to the invention, wherein the method comprises a step of controlling an opening degree of the bypass valve based on a differential temperature of the heat transfer medium between an inlet of the first heat exchanger and an outlet of the first heat exchanger.

[0022] The method can be characterized in that an opening degree of an expansion device of the heating and/or cooling part is controlled based on a degree of superheat determined from a temperature sensor and a pressure sensor at the discharge line of a compressor of the refrigerant circuit. The control is preferably such that if the determined degree of superheat is higher than a predetermined value, the opening degree of the expansion device is increased and/or if the determined degree of superheat is lower than a predetermined value, the opening degree of the expansion device is decreased.

[0023] In the method, the speed of a compressor of the system can be controlled based on the temperature of the heat transfer medium. The control is preferably such that the speed of the compressor is increased if the temperature of the phase change material is higher than the phase change temperature of the phase change material and/or the speed of the compressor is decreased if the temperature of the phase change material is lower than the phase change temperature of the phase change material. The temperature of the phase change material is preferably obtained from a temperature sensor at an inlet of the first heat exchanger.

[0024] Furthermore, in the method, the opening degree of the bypass valve can be controlled based on a differential temperature of the heat transfer medium between an inlet of the first heat exchanger and an outlet of the first heat exchanger. The control is preferably such that the opening degree of the bypass valve is increased if the differential temperature is lower than a predetermined set point and/or the opening degree of the bypass valve is decreased if the differential temperature is higher than a predetermined set point. The differential temperature is preferably calculated from a temperature obtained from a temperature sensor at an inlet of the first heat exchanger and from a temperature obtained from a temperature sensor at an outlet of the first heat exchanger.

[0025] Moreover, in the method, a conveying speed of the pump can be controlled based on a cooling capacity determined from the current flow rate of the heat transfer medium and determined from a differential temperature of the heat transfer medium between an inlet of the first heat exchanger and an outlet of the first heat exchanger. The control is preferably such that the conveying speed of the pump is increased if the cooling capacity is lower than a predetermined set point and/or the conveying speed of the pump (P) is decreased if the cooling capacity is higher than a predetermined set point. The current flow of the heat transfer medium is preferably obtained from the pump and the differential temperature is preferably calculated from a temperature obtained from a temperature sensor at an inlet of the first heat exchanger and from a temperature obtained from a temperature sensor at an outlet of the first heat exchanger.

[0026] With reference to the following Figures and Example, the subject according to the invention is intended to be explained in more detail without wishing to restrict said subject to the special embodiments shown here.

Figure 1 shows a schematic drawing of an air conditioning system according to the invention. The refrigerant circuit RC comprises a compressor Comp, a condenser Cond, an expansion device LEV, a liquid separator LS, two valves V1, V2 and a first heat exchanger PHEX and is comprised by an outdoor unit. Refrigerant circulates through the refrigerant circuit. The first heat exchanger PHEX is in thermal connection with a slurry circuit SC. The slurry circuit SC comprises a pump P, a main valve SMV and a bypass valve BPV within a bypass line BL, which are comprised by a hydronic box HB, and further comprises a second heat exchanger HEX2 and a third heat exchanger HEX3 which are comprised by an indoor unit IU. A slurry of a phase change material circulates through the slurry circuit SC.

Figure 2 shows a schematic drawing of an architecture of the controller of an air conditioning system according to the invention. The controller controls the opening degree of the expansion device of the refrigerant circuit to determine the degree of superheat in the refrigerant circuit. Furthermore, the controller controls the speed of the compressor of the refrigerant circuit to determine the cooling capacity of the refrigerant. Moreover, the controller controls the opening degree of the bypass valve of the slurry circuit to determine the cooling capacity of the second and third heat exchanger of the indoor unit. Besides, the controller controls the speed of the pump of the slurry circuit to further determine the cooling capacity of the second and third heat exchanger of the indoor unit. "e(t)" is the control error which equals to the setpoint of controlled variable (CV) minus the measurement of CV. "SH" is the super heat, which is defined as the differential temperature of measured temperate of gas phase and the saturation temperature under same pressure. "ΔT_{pcs}" is the differential temperature of phase change slurry between inlet and outlet at first heat exchanger PHEX ($\Delta T_{pcs} = T_{PCS,inlet} - T_{PCS,outlet}$). "$T_{PCs,inlet}$" is the temperature of the heat transfer medium containing the phase change material at the inlet of the first heat exchanger. "Q_{HEX}" is the heat transfer rate of the first heat exchanger PHEX (or its cooling capacity).

Figure 3 shows a schematic drawing of an alternative architecture of the controller of an air conditioning system according to the invention. The controller controls the opening degree of the expansion device of the refrigerant circuit to determine the degree of superheat in the refrigerant circuit. Furthermore, the controller controls the speed of the compressor of the refrigerant circuit to determine the cooling capacity of the refrigerant. Moreover, the controller controls the opening degree of the bypass valve of the slurry circuit to determine the cooling capacity of the second and third heat exchanger of the indoor unit. Besides, the controller controls the speed of the pump of the slurry circuit to further determine the cooling capacity of the second and third heat exchanger of the indoor unit. "e(t)" is the control error which equals to the setpoint of controlled variable (CV) minus the measurement of CV. "SH" is the super heat, which is defined as the differential temperature of measured temperate of gas phase and the saturation temperature under same pressure. "ΔT_{pcs}" is the differential temperature of phase change slurry between inlet and outlet at first heat exchanger PHEX ($\Delta T_{pcs} = T_{PCS,inlet} - T_{PCs,outlet}$). "$T_{PCS,inlet}$" is the temperature of the heat transfer medium containing the phase change material at the inlet of the first heat exchanger. ""T_{indoor}" is the indoor temperature value which be measured by a thermostatic sensor.

Figure 4 shows the pressure loss in dependence of the opening degree of the bypass valve (in %). By adjusting the opening degree of the bypass valve by the controller, it can be ensured the operation temperature of the slurry will span across the phase change temperature of the phase change material, which is related to the concentration of PCM. By doing so, a minimum flow rate for the slurry circuit can be achieved.

Figures 5 to 8 show a control and performance of several actuators of a system according to the invention over time. Figure 5 shows the control and performance of the compressor of the heating and/or cooling part (refrigerant circuit). Figure 6 shows the control and the performance of the expansion device of the heating and/or cooling part (refrigerant circuit). Figure 7 shows the control and performance of the bypass valve of the slurry circuit. Figure 8 shows the control and performance of the pump of the slurry circuit.

Example - **Method according to the invention**

[0027] For controlling the air conditioning system, a bypass line is present in the heat transfer circuit of the system to bypass at least one indoor heat exchanger (second heat exchanger and optionally third heat exchanger).

[0028] The flow rate of the medium containing the phase change material (PCM) can be controlled by the controller of the system. The functions of the following parts of the system is highlighted:

The expansion device of the refrigerant circuit mainly ensures the superheat (SH) at the suction line of the compressor has a predetermined value, so the compressor will be running safely. The measured superheat will be compared with a setpoint first, then an error value is calculated and then passed to the controller. For example, if the measurement value is higher than the setpoint, the controller will send a control signal to the expansion device in which openness of the expansion device will increase so that more refrigerant flow will be present in the evaporator then the super heat will reduce.

[0029] The compressor of the refrigerant circuit mainly keeps the temperature of the PCS at the inlet of the first heat exchanger slightly higher than the melting (equilibrium) temperature of the PCM. The controller is using the compressor to control the inlet temperature of the medium containing the PCM at the inlet of the first heat exchanger on the side of the heat transfer circuit. The measured medium temperature is compared with a setpoint, an error is calculated and then a value is feed to the controller. The controller will output a signal to the compressor based on the error value. For example, if the measurement is lower than the setpoint, the controller will output an increased frequency value to the compressor in which compressor will operate harder and bring down the evaporation temperature. Then, the inlet temperature of the medium containing PCM will lower towards the setpoint.

[0030] The pump of the heat transfer circuit modulates the flow rate of the medium containing PCM to set said medium to a predetermined temperature (preferably essentially the phase change temperature of the heat medium) at an exit of the first heat exchanger, so that the PCM material in the medium has its maximum cooling capacity (melting enthalpy of the PCM material). The cooling capacity is calculated based on the flow rate of the medium containing the PCM and a differential temperature of the medium containing the PCM, the measurement is compared with a setpoint, then an error value is obtained and a value fed to the controller. The controller will output the pump speed signal accordingly. For example, if measured value is lower than the setpoint, the controller will increase pump speed so more medium containing PCM will be pumped to the indoor unit heat exchanger to increase the cooling capacity toward to its setpoint. Alternatively, if the indoor temperature is used as CV the measurement is taken at a constant interval and then compared with the setpoint. An error value is calculated and then fed into the controller. The controller then outputs a control signal to the actuator pump. For example, if the indoor temperature is higher than the setpoint, the controller will increase the pump speed so more medium containing the PCM will be fed into indoor unit to reduce the indoor room temperature.

[0031] The bypass valve in the heat transfer circuit tunes the flow rate of medium containing the PCM to ensure that the system will deliver the right cooling capacity to the indoor heat exchanger and maintains a desired indoor room temperature according to a setpoint. The controller is using the bypass valve (e.g. a stepper motorized valve) to control the differential temperature of the medium containing the PCM which flows between the inlet and the outlet of the first heat exchanger. ΔT_{PCS} is measured by two temperature sensors at the inlet and outlet of the first heat exchanger and then compared with a setpoint so an error value will be calculated and fed to the controller. The controller will output the control signal according to the value to the bypass valve. For example, if the measurement value is lower than the setpoint, the bypass valve will increase its openness so more flow will be pumped in the slurry circuit. Then, the differential temperature will reduce towards the setpoint.

List of reference signs

[0032]

RC:	refrigerant circuit (heating and/or cooling part);
SC:	slurry circuit (heat transfer circuit);
PHEX:	first heat exchanger;
FP:	first part of first heat exchanger;
SP:	second part of first heat exchanger;
HEX2:	second heat exchanger;
HEX3:	third heat exchanger;
IU:	indoor unit (in indoor space);
OU:	outdoor unit (in outdoor space);
HB:	hydronic box;
P:	Pump;
BL:	bypass line;
BPV:	bypass valve (e.g. a stepper motorized valve);
LEV:	expansion device (e.g. an expansion valve);
Comp:	compressor;
Cond:	condenser;
LS:	liquid separator;
V1, V2:	valves of the refrigerant circuit.

Claims

1. Air conditioning system comprising
a heating and/or cooling part (RC) comprising a first part (FP) of a first heat exchanger (PHEX), wherein the first heat exchanger (PHEX) comprises the first part (FP) and a second part (SP) and is configured to exchange heat between the first part (FP) and second part (SP),
a heat transfer circuit (SC) comprising the second part (SP) of the first heat exchanger (PHEX) and further comprising
a pump (P) configured to circulate a heat transfer medium in the heat transfer circuit (SC),
a second heat exchanger (HEX2) configured to transfer heat between the heat transfer medium and an indoor space (IU), and
a bypass line (BL) bypassing the second heat exchanger (HEX2), wherein the bypass line (BL) comprises a bypass valve (BPV) between a first and a second end of the bypass line (BL), the bypass valve (BPV) being configured to control a flow through the bypass line (BL), wherein the heat transfer circuit (SC) comprises a heat transfer medium, which is configured to be circulated in the heat transfer circuit (SC), wherein the heat transfer medium contains a phase change material; and
a controller which is configured to control an opening degree of the bypass valve (BPV).

2. Air conditioning system according to the preceding claim, wherein the heating and/or cooling part is a refrigerant circuit comprising a compressor (Comp), a condenser (Cond), an expansion device (LEV), a liquid separator (LS) and a refrigerant.

3. Air conditioning system according to one of the preceding claims, wherein the bypass line (BL) branches off from a main circuit of the heat transfer circuit (SC) between the pump (P) and the second heat exchanger (HEX2) on its first end and branches of the main circuit between the second part of the first heat exchanger (PHEX) and the second heat exchanger (HEX2) on its second end.

4. Air conditioning system according to one of the preceding claims, wherein the heat transfer circuit (SC) further comprises

i) a third heat exchanger (HEX3) which is configured to transfer heat between the heat transfer medium and an indoor space; and/or
ii) a storage device for storing the phase change material (PCM).

5. Air conditioning system according to one of the preceding claims, wherein the phase change material

i) is present in the heat transfer medium in the form of a dispersion of solid phase change material in a liquid, preferably is present in the heat transfer medium in the form of a slurry; and/or
ii) is present in the heat transfer medium in a concentration of 5 to 20 wt.-%, preferably 7 to 15 wt.-%, more preferably 8 to 12, especially 10 wt.-%, relative to the total weight of the heat transfer medium; and/or
iii) has a phase change temperature in the range of -5 °C to 10 °C, preferably -5 °C to 5 °C.

6. Air conditioning system according to one of the preceding claims, wherein the system comprises

i) in the heat transfer circuit (SC), a temperature sensor (TS1) at a first end of the second part of the first heat exchanger; and/or
ii) in the heat transfer circuit (SC), a temperature sensor (TS2) at a second end of the second part of the first heat exchanger; and/or
iii) in the refrigerant circuit, a temperature sensor (TS3) and a pressure sensor (PS) at the discharge line of a compressor (Comp) of the refrigerant circuit.

7. Air conditioning system according to one of the preceding claims, wherein the controller is configured to control an opening degree of an expansion device of the heating and/or cooling part based on a degree of superheat determined from a temperature sensor (TS3) and a pressure sensor (PS) at the discharge line of a compressor (Comp) of the refrigerant circuit, preferably such that

i) if the determined degree of superheat is higher than a predetermined value, the opening degree of the expansion device (LEV) is increased; and/or
ii) if the determined degree of superheat is lower than a predetermined value, the opening degree of the expansion device (LEV) is decreased.

8. Air conditioning system according to one of the preceding claims, wherein the controller is configured to control the speed of a compressor (Comp) of the system based on the temperature of the heat transfer medium, preferably such that

i) the speed of the compressor (Comp) is increased if the temperature of the phase change material is higher than the phase change temperature of the phase change material; and/or
ii) the speed of the compressor (Comp) is decreased if the temperature of the phase change material is lower than the phase change temperature of the phase change material;

wherein the temperature of the phase change material is preferably obtained from a temperature sensor (TS1) at an inlet of the first heat exchanger (PHEX).

9. Air conditioning system according to one of the preceding claims, wherein the controller is configured to control the opening degree of the bypass valve (BPV) based on a differential temperature of the heat transfer medium between an inlet of the first heat exchanger (PHEX) and an outlet of the first heat exchanger (PHEX), preferably such that

i) the opening degree of the bypass valve (BPV) is increased if the differential temperature is lower than a predetermined set point; and/or
ii) the opening degree of the bypass valve (BPV) is decreased if the differential temperature is higher than a predetermined set point; and/or

wherein the differential temperature is preferably calculated from a temperature obtained from a temperature sensor (TS1) at an inlet of the first heat exchanger (PHEX) and from a temperature obtained from a temperature sensor (TS2) at an outlet of the first heat exchanger (PHEX).

10. Air conditioning system according to one of the preceding claims, wherein the controller is configured to control the conveying speed of the pump (P) based on a cooling capacity determined from the current flow rate of the heat transfer medium and determined from a differential temperature of the heat transfer medium between an inlet of the first heat exchanger (PHEX) and an outlet of the first heat exchanger (PHEX), preferably such that

i) the conveying speed of the pump (P) is increased if the cooling capacity is lower than a predetermined set point; and/or
ii) the conveying speed of the pump (P) is decreased if the cooling capacity is higher than a predetermined set point;

wherein the current flow of the heat transfer medium is preferably obtained from the pump (P) and the differential temperature is preferably calculated from a temperature obtained from a temperature sensor (TS1) at an inlet of the first heat exchanger (PHEX) and from a temperature obtained from a temperature sensor (TS2) at an outlet of the first heat exchanger (PHEX).

11. Method for controlling an air conditioning system according to one of the preceding claims, wherein the method comprises a step of controlling an opening degree of the bypass valve (BPV) based on a differential temperature of the heat transfer medium between an inlet of the first heat exchanger (PHEX) and an outlet of the first heat exchanger (PHEX).

12. Method according to claim 11, wherein an opening degree of an expansion device of the heating and/or cooling part is controlled based on a degree of superheat determined from a temperature sensor (TS3) and a pressure sensor (PS) at the discharge line of a compressor (Comp) of the refrigerant circuit, preferably such that

i) if the determined degree of superheat is higher than a predetermined value, the opening degree of the expansion device is increased; and/or
ii) if the determined degree of superheat is lower than a predetermined value, the opening degree of the expansion device is decreased.

13. Method according to one of claims 11 and 12, wherein the speed of a compressor (Comp) of the system is controlled based on the temperature of the heat transfer medium, preferably such that

i) the speed of the compressor (Comp) is increased if the temperature of the phase change material is higher than the phase change temperature of the phase change material; and/or
ii) the speed of the compressor (Comp) is decreased if the temperature of the phase change material is lower than the phase change temperature of the phase change material;

wherein the temperature of the phase change material is preferably obtained from a temperature sensor (TS1) at an inlet of the first heat exchanger (PHEX).

14. Method according to one of claims 11 to 13, wherein the opening degree of the bypass valve (BPV) is controlled based on a differential temperature of the heat transfer medium between an inlet of the first heat exchanger (PHEX) and an outlet of the first heat exchanger (PHEX), preferably such that

i) the opening degree of the bypass valve (BPV) is increased if the differential temperature is lower than a predetermined set point; and/or
ii) the opening degree of the bypass valve (BPV) is decreased if the differential temperature is higher than a predetermined set point;

wherein the differential temperature is preferably calculated from a temperature obtained from a temperature sensor (TS1) at an inlet of the first heat exchanger (PHEX) and from a temperature obtained from a temperature sensor (TS2) at an outlet of the first heat exchanger (PHEX).

15. Method according to one of claims 11 to 14, wherein a conveying speed of the pump (P) is controlled based on a cooling capacity determined from the current flow rate of the heat transfer medium and determined from a differential temperature of the heat transfer medium between an inlet of the first heat exchanger (PHEX) and an outlet of the first heat exchanger (PHEX), preferably such that

i) the conveying speed of the pump (P) is increased if the cooling capacity is lower than a predetermined set point; and/or
ii) the conveying speed of the pump (P) is decreased if the cooling capacity is higher than a predetermined set point;

wherein the current flow of the heat transfer medium is preferably obtained from the pump (P) and the differential temperature is preferably calculated from a temperature obtained from a temperature sensor (TS1) at an inlet of the first heat exchanger (PHEX) and from a temperature obtained from a temperature sensor (TS2) at an outlet of the first heat exchanger (PHEX).

Figure 1

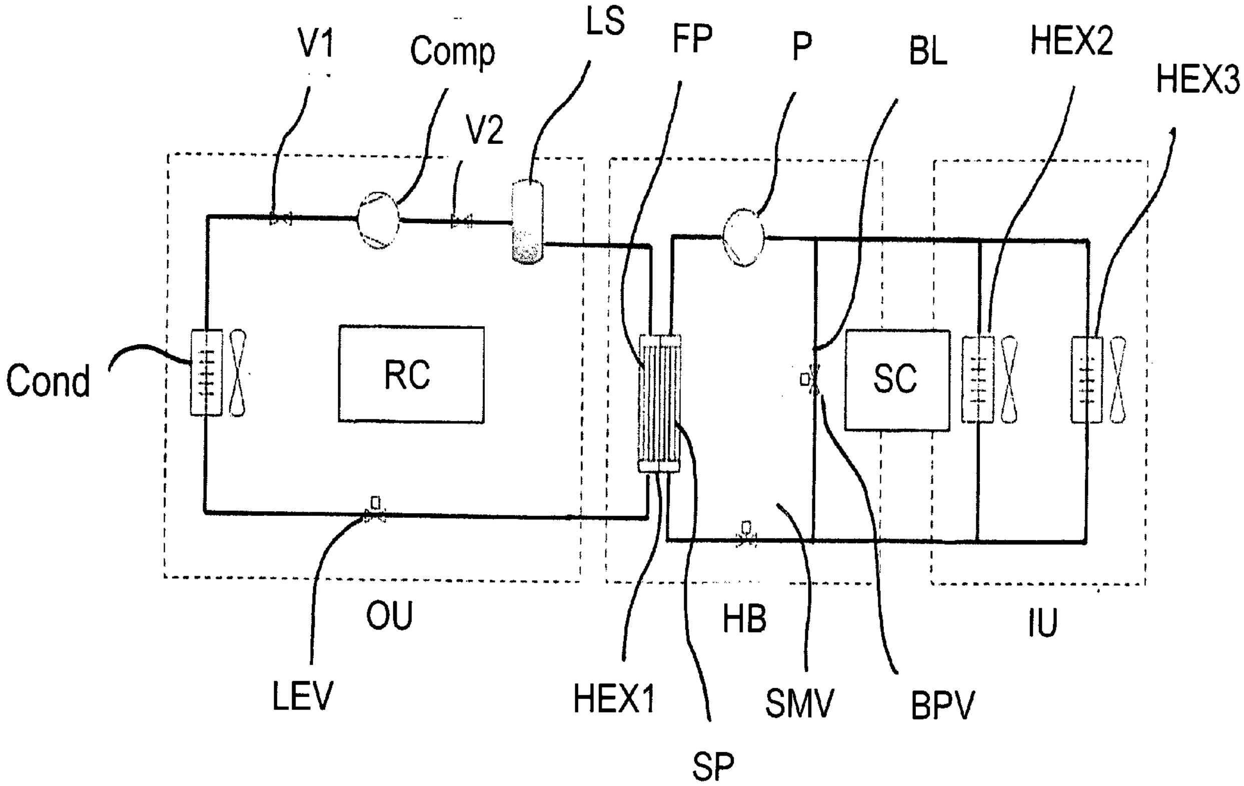

V1
Comp
LS
V2
FP
P
BL
HEX2
HEX3
Cond
RC
SC
OU
HB
IU
LEV
HEX1
SP
SMV
BPV

Figure 2

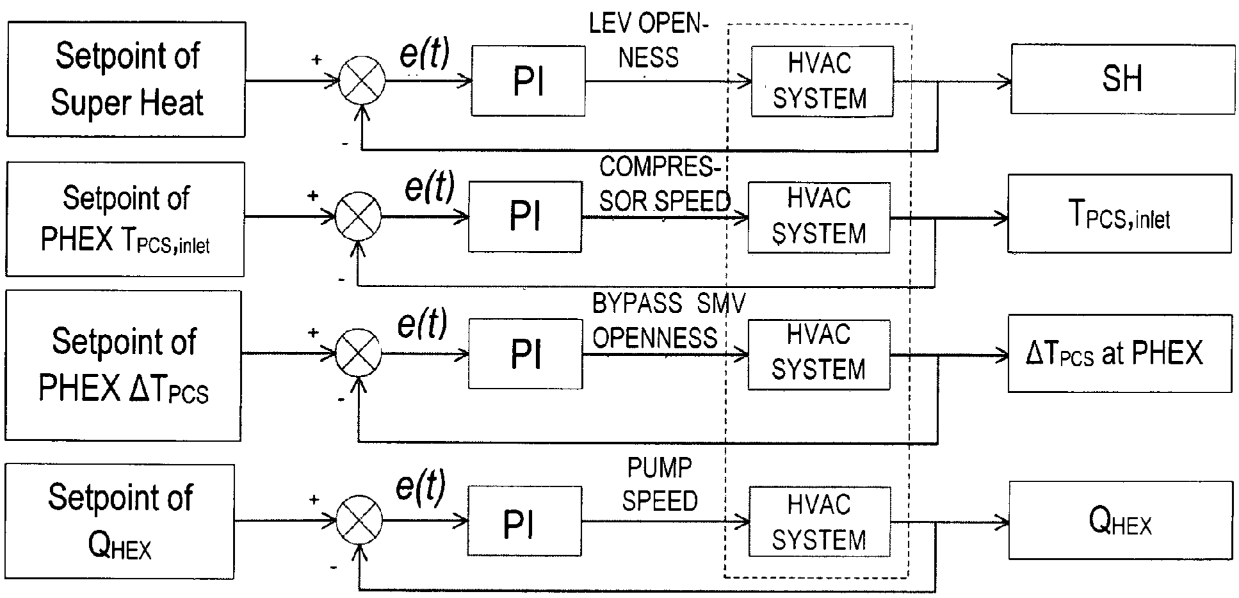
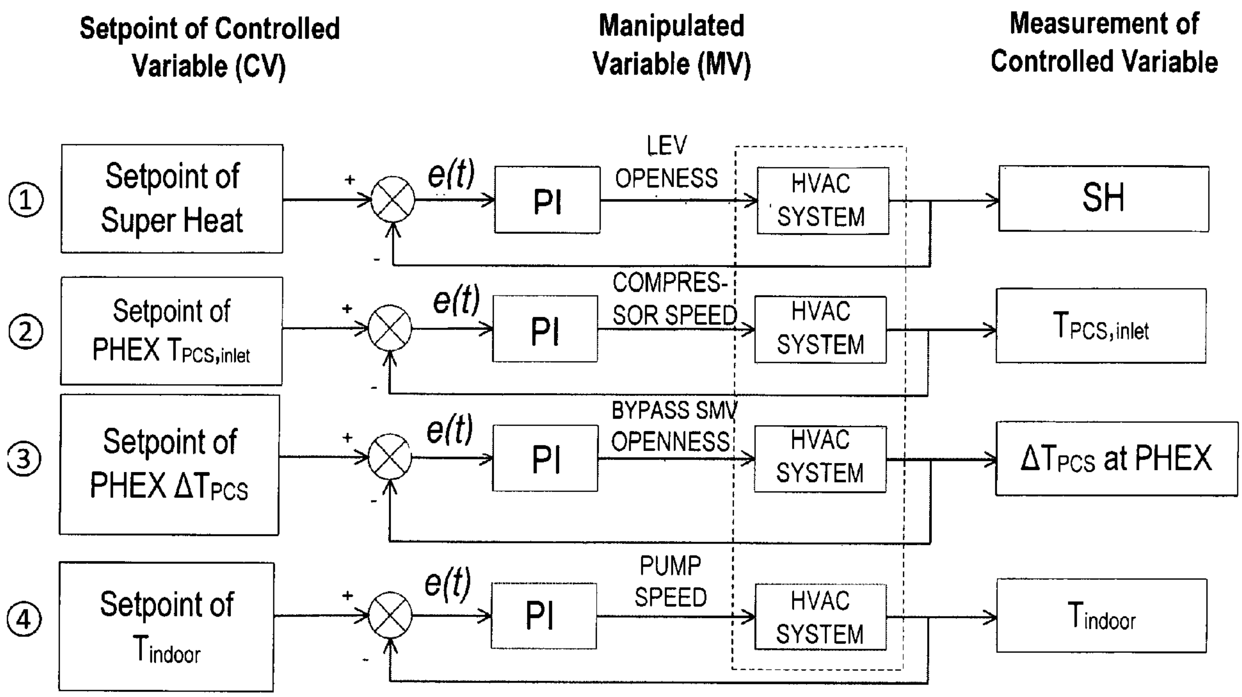

Setpoint of Super Heat
+
-
e(t)
PI
LEV OPEN-NESS
HVAC SYSTEM
SH
Setpoint of PHEX TPCS,inlet
e(t)
PI
COMPRES-SOR SPEED
HVAC SYSTEM
TPCS,inlet
Setpoint of PHEX ΔTPCS
e(t)
PI
BYPASS SMV OPENNESS
HVAC SYSTEM
ΔTPCS at PHEX
Setpoint of QHEX
e(t)
PI
PUMP SPEED
HVAC SYSTEM
QHEX

Figure 3


Setpoint of Controlled Variable (CV)
Manipulated Variable (MV)
Measurement of Controlled Variable
①
Setpoint of Super Heat
e(t)
PI
LEV OPENESS
HVAC SYSTEM
SH
②
Setpoint of PHEX TPCS,inlet
e(t)
PI
COMPRES-SOR SPEED
HVAC SYSTEM
TPCS,inlet
③
Setpoint of PHEX ΔTPCS
e(t)
PI
BYPASS SMV OPENNESS
HVAC SYSTEM
ΔTPCS at PHEX
④
Setpoint of Tindoor
e(t)
PI
PUMP SPEED
HVAC SYSTEM
Tindoor

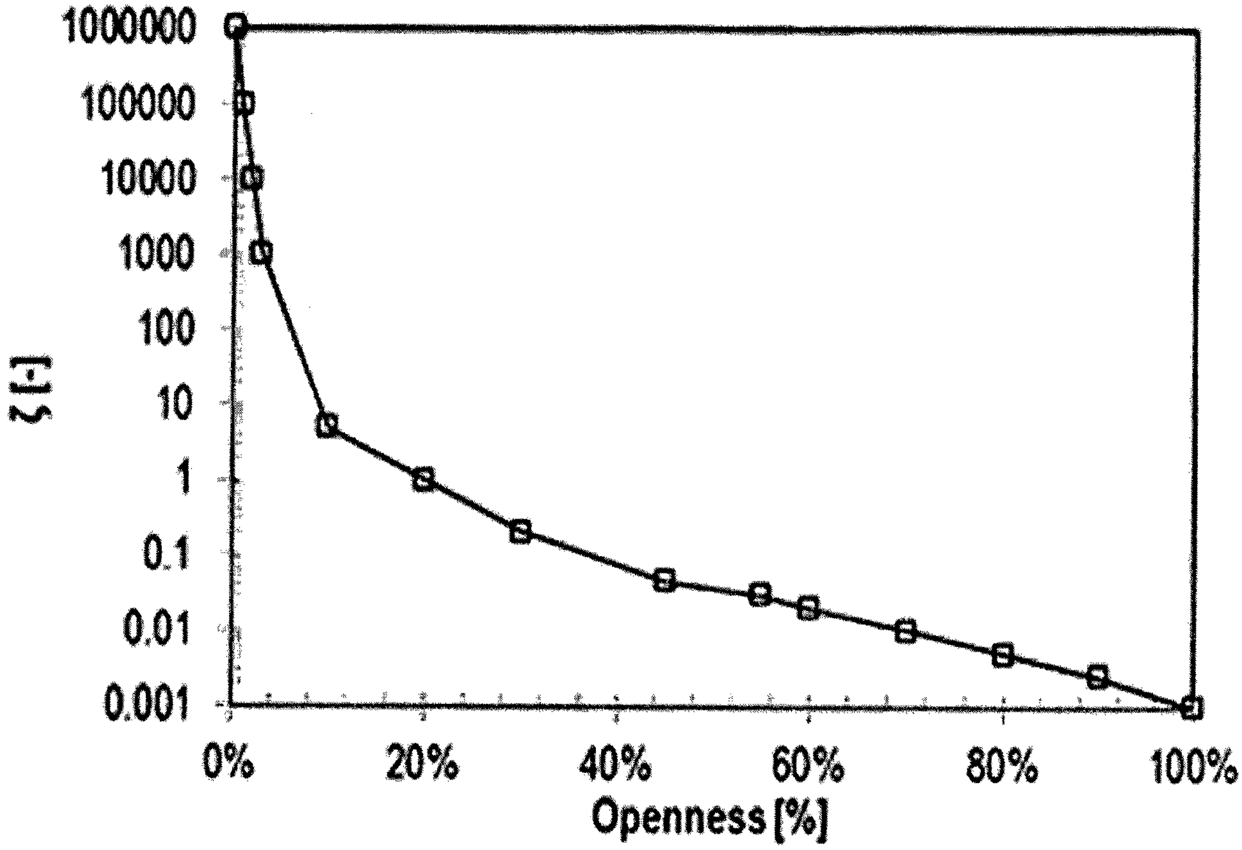
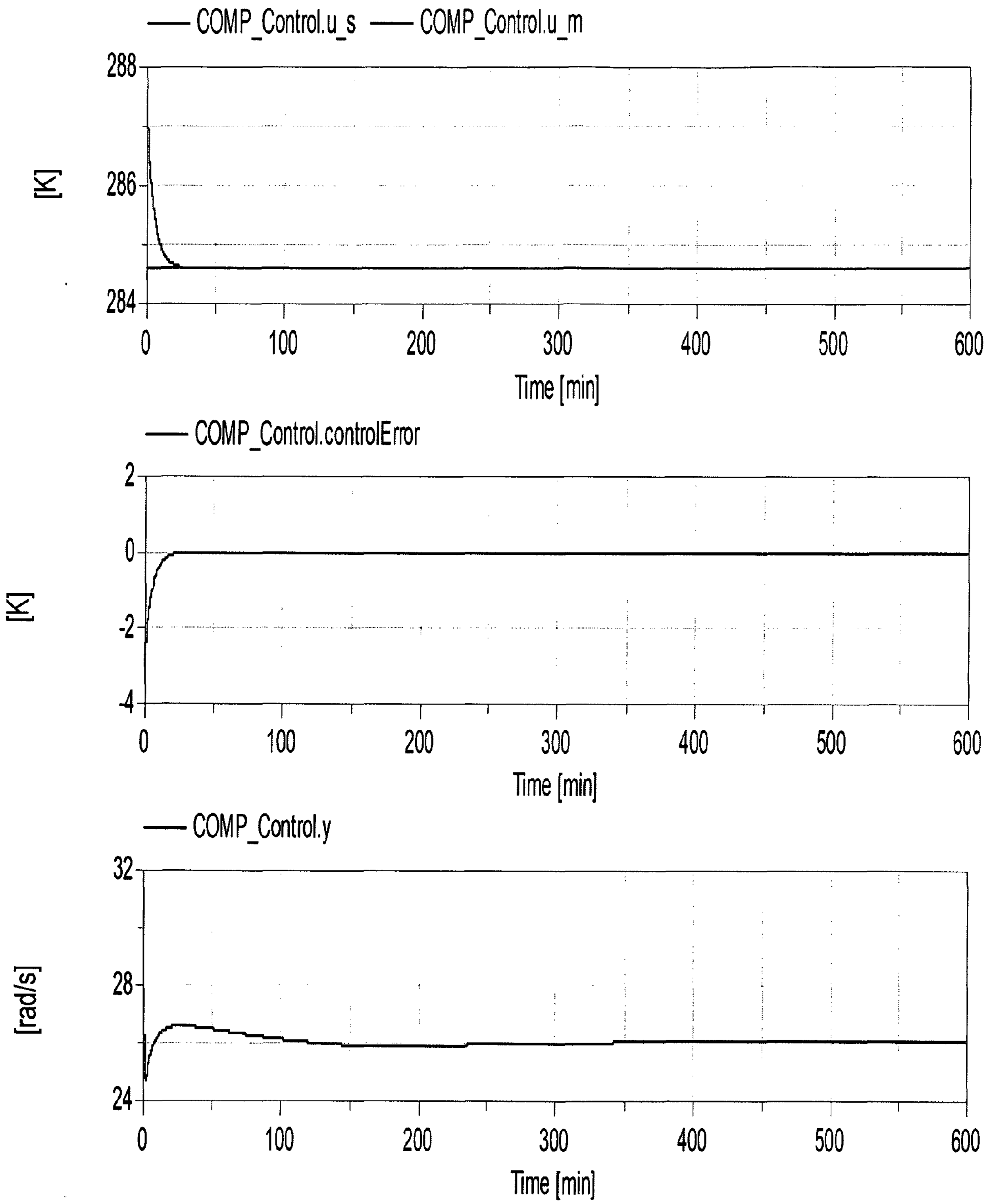

1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
ζ [-]
0%
20%
40%
60%
80%
100%
Openness [%]

Figure 5


COMP_Control.u_s
COMP_Control.u_m
288
286
284
[K]
0
100
200
300
400
500
600
Time [min]
COMP_Control.controlError
2
0
-2
-4
[K]
Time [min]
COMP_Control.y
32
28
24
[rad/s]
Time [min]

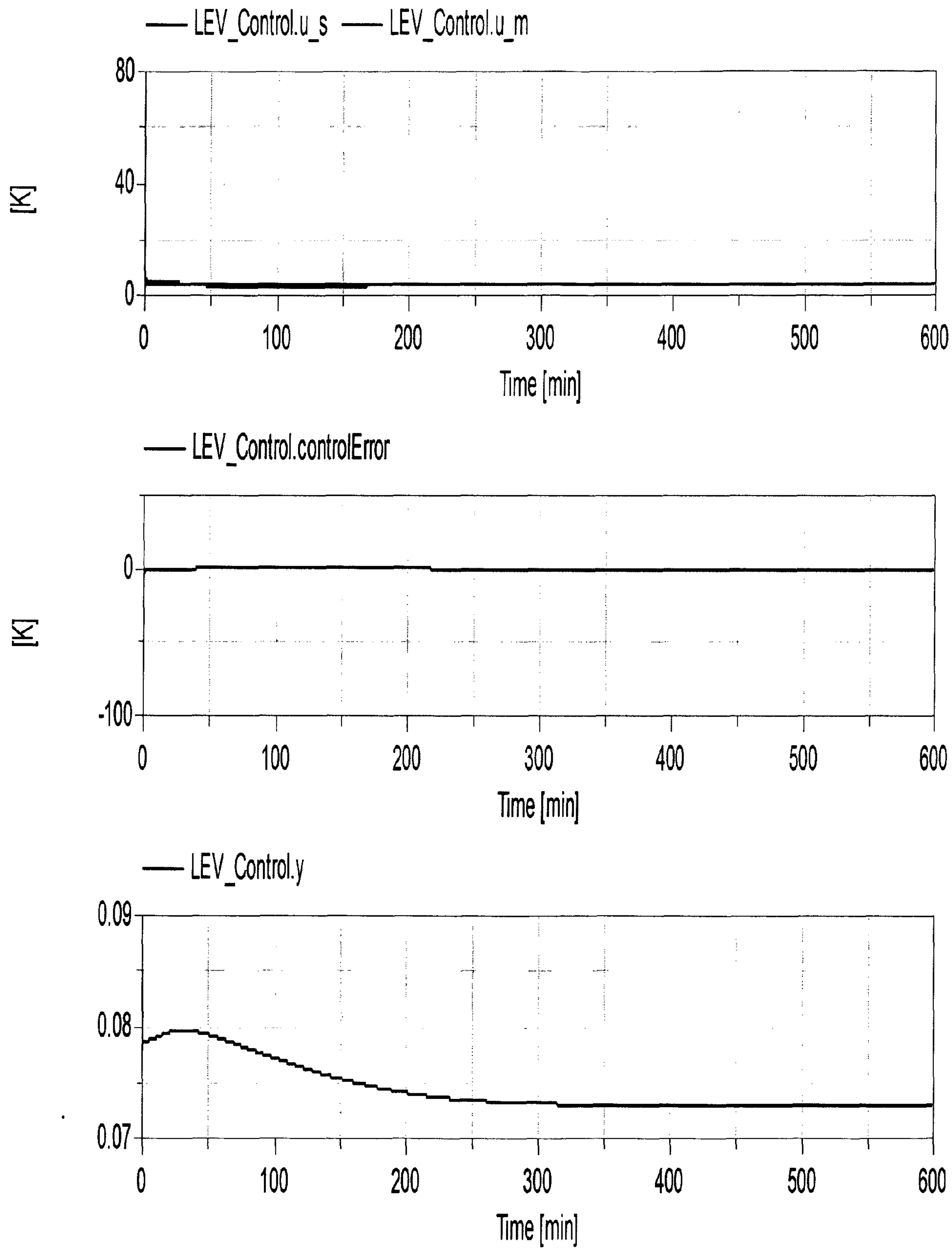

LEV_Control.u_s
LEV_Control.u_m
[K]
80
40
0
0
100
200
300
400
500
600
Time [min]
LEV_Control.controlError
[K]
0
-100
0
100
200
300
400
500
600
Time [min]
LEV_Control.y
0.09
0.08
0.07
0
100
200
300
400
500
600
Time [min]

Figure 7

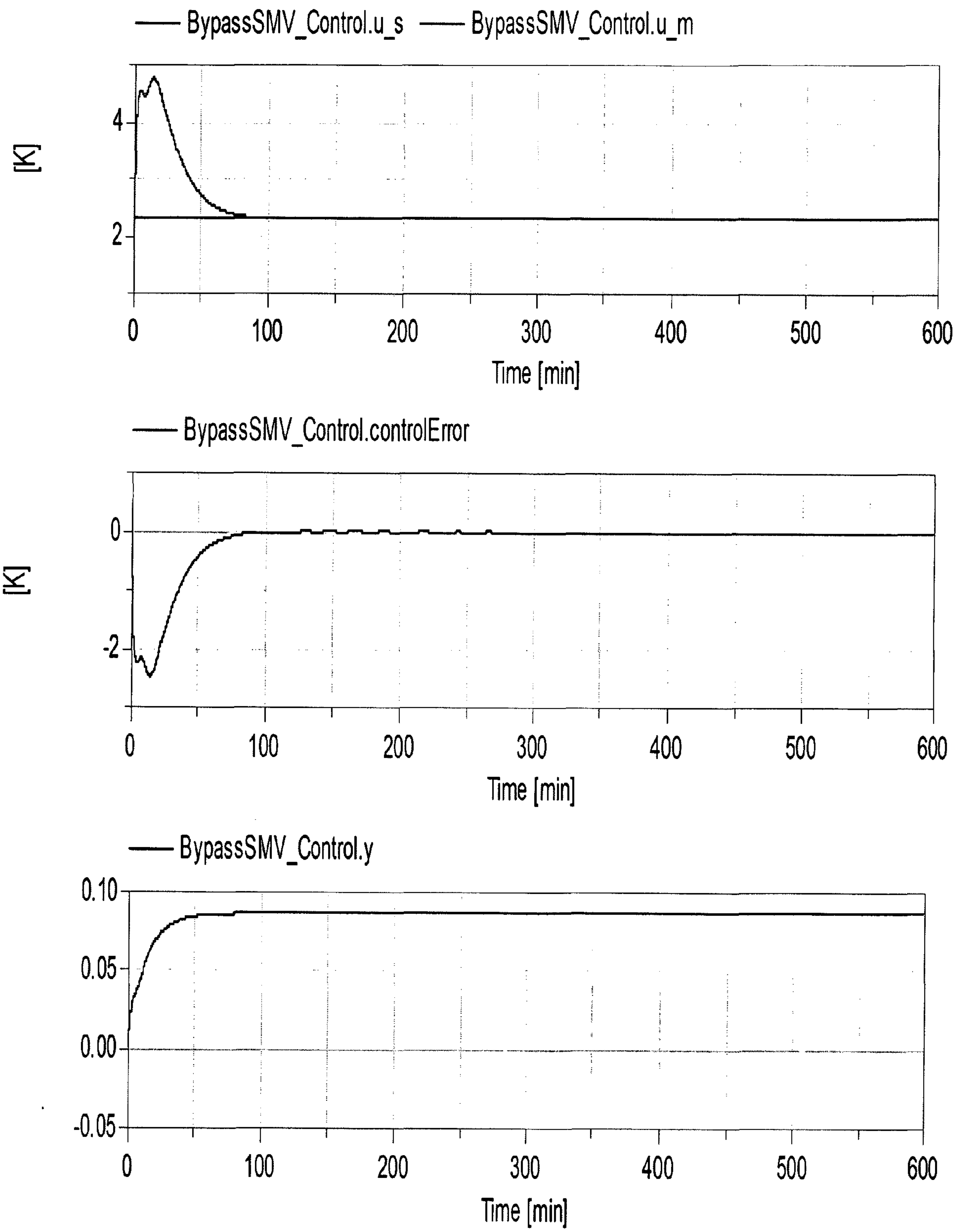
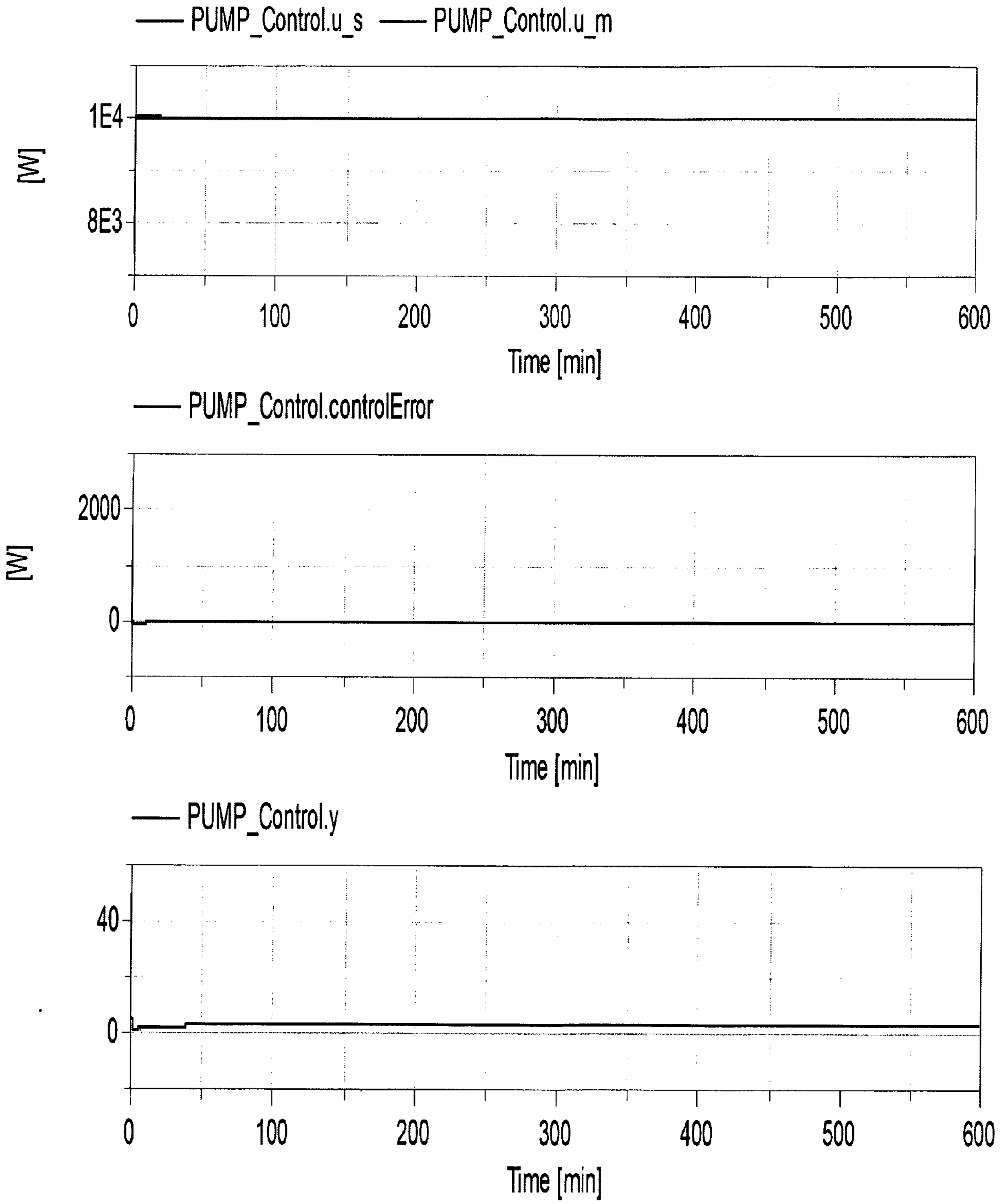

BypassSMV_Control.u_s
BypassSMV_Control.u_m
[K]
4
2
0
100
200
300
400
500
600
Time [min]
BypassSMV_Control.controlError
[K]
0
-2
0
100
200
300
400
500
600
Time [min]
BypassSMV_Control.y
0.10
0.05
0.00
-0.05
0
100
200
300
400
500
600
Time [min]

Figure 8


PUMP_Control.u_s
PUMP_Control.u_m
1E4
8E3
[W]
0
100
200
300
400
500
600
Time [min]
PUMP_Control.controlError
2000
0
[W]
0
100
200
300
400
500
600
Time [min]
PUMP_Control.y
40
0
0
100
200
300
400
500
600
Time [min]

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 20 19 3681

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y A	WO 2007/146050 A2 (WATERS HOT INC [US]; FLAMMANG KEVIN E [US] ET AL.) 21 December 2007 (2007-12-21) * page 33, line 28 to page 34, line 26;; page 24, line 14 - line 21; figures 4,8A * -----	1-5,11 6 7-10, 12-15	INV. F25B25/00 F25B49/02
Y	US 2016/061534 A1 (CHOI PETER B [US]) 3 March 2016 (2016-03-03) * paragraph [0002] - paragraph [0017] * -----	6	
Y	CN 102 519 097 A (UNIV SHANGHAI JIAOTONG) 27 June 2012 (2012-06-27) * abstract * -----	6	
A	US 2015/047379 A1 (HONDA TAKAYOSHI [JP] ET AL) 19 February 2015 (2015-02-19) * the whole document * -----	1-15	
A	EP 2 767 773 A1 (DAIKIN IND LTD [JP]) 20 August 2014 (2014-08-20) * the whole document * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	26 January 2021	Gasper, Ralf

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 20 19 3681

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-01-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2007146050 A2	21-12-2007	AU 2007258621 A1	21-12-2007
		BR PI0712184 A2	17-01-2012
		CA 2659584 A1	21-12-2007
		EP 2024693 A2	18-02-2009
		JP 2009540258 A	19-11-2009
		KR 20090021213 A	27-02-2009
		US 2010018228 A1	28-01-2010
		WO 2007146050 A2	21-12-2007
US 2016061534 A1	03-03-2016	NONE	
CN 102519097 A	27-06-2012	NONE	
US 2015047379 A1	19-02-2015	CN 104395678 A	04-03-2015
		EP 2868992 A1	06-05-2015
		JP 5931189 B2	08-06-2016
		JP WO2013171781 A1	07-01-2016
		US 2015047379 A1	19-02-2015
		WO 2013171781 A1	21-11-2013
EP 2767773 A1	20-08-2014	CN 103842733 A	04-06-2014
		EP 2767773 A1	20-08-2014
		JP 5327308 B2	30-10-2013
		JP 2013083421 A	09-05-2013
		US 2014230477 A1	21-08-2014
		WO 2013046720 A1	04-04-2013

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 104673191 A **[0005]**
- US 6237346 B1 **[0006]**
- US 20170307263 A1 **[0007]**