US 20160033169A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2016/0033169 A1
HANTSCHEL
(43) Pub. Date: Feb. 4, 2016

(54) **HEATING DEVICE**

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(21) Appl. No.: **14/774,850**

(22) PCT Filed: **Nov. 27, 2013**

(86) PCT No.: **PCT/EP2013/074869**
§ 371 (c)(1),
(2) Date: **Sep. 11, 2015**

(30) **Foreign Application Priority Data**

Mar. 12, 2013 (DE) 10 2013 102 465.3

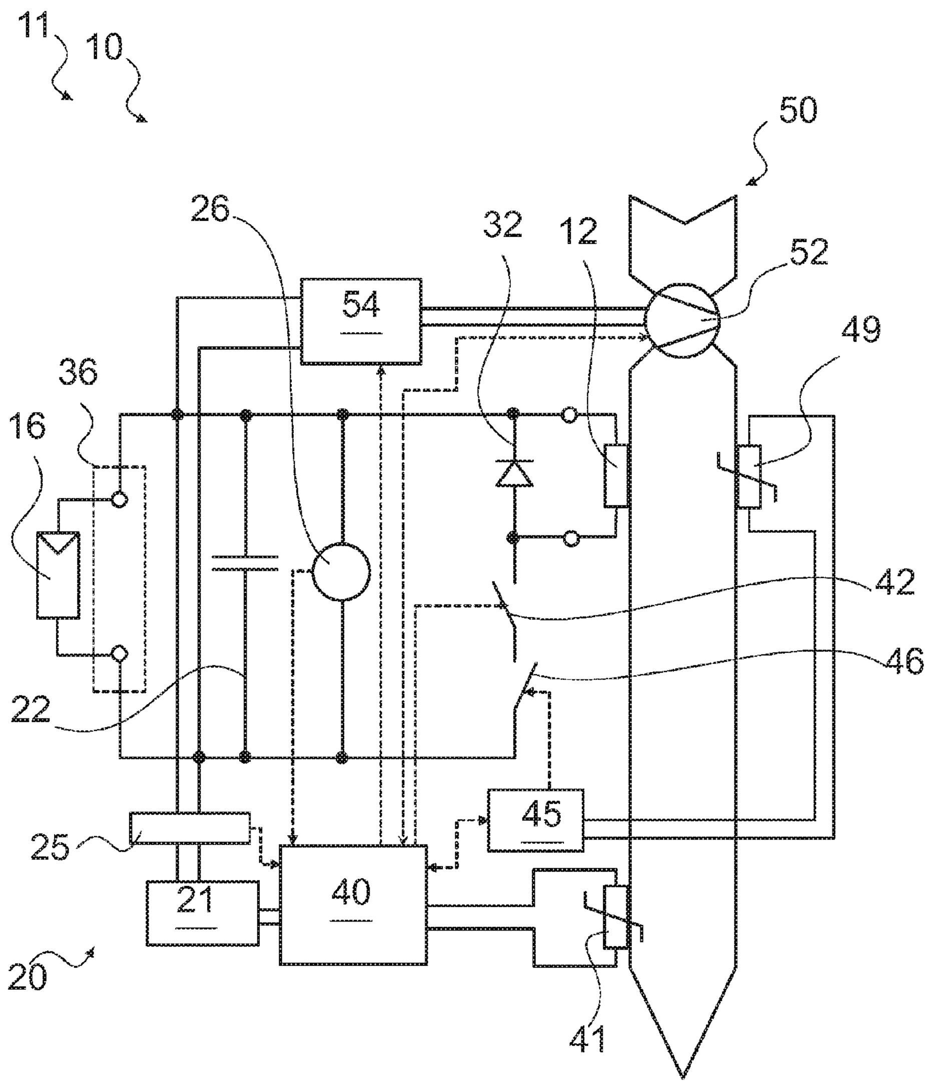
Publication Classification

(51) **Int. Cl.**
F24H 9/20 (2006.01)
F24D 19/10 (2006.01)

(52) **U.S. Cl.**
CPC ***F24H 9/20*** (2013.01); ***F24D 19/10*** (2013.01); *F24H 2250/02* (2013.01)

(57) **ABSTRACT**

A heating device, in particular for heating at least one fluid, includes at least one first heating resistor and at least one supply electronics unit, which is provided for supplying at least the first heating resistor with current provided by at least one first photovoltaic plant. It is proposed that the supply electronics unit is provided for operating at least the first heating resistor in a clocked manner at least in one operating mode.



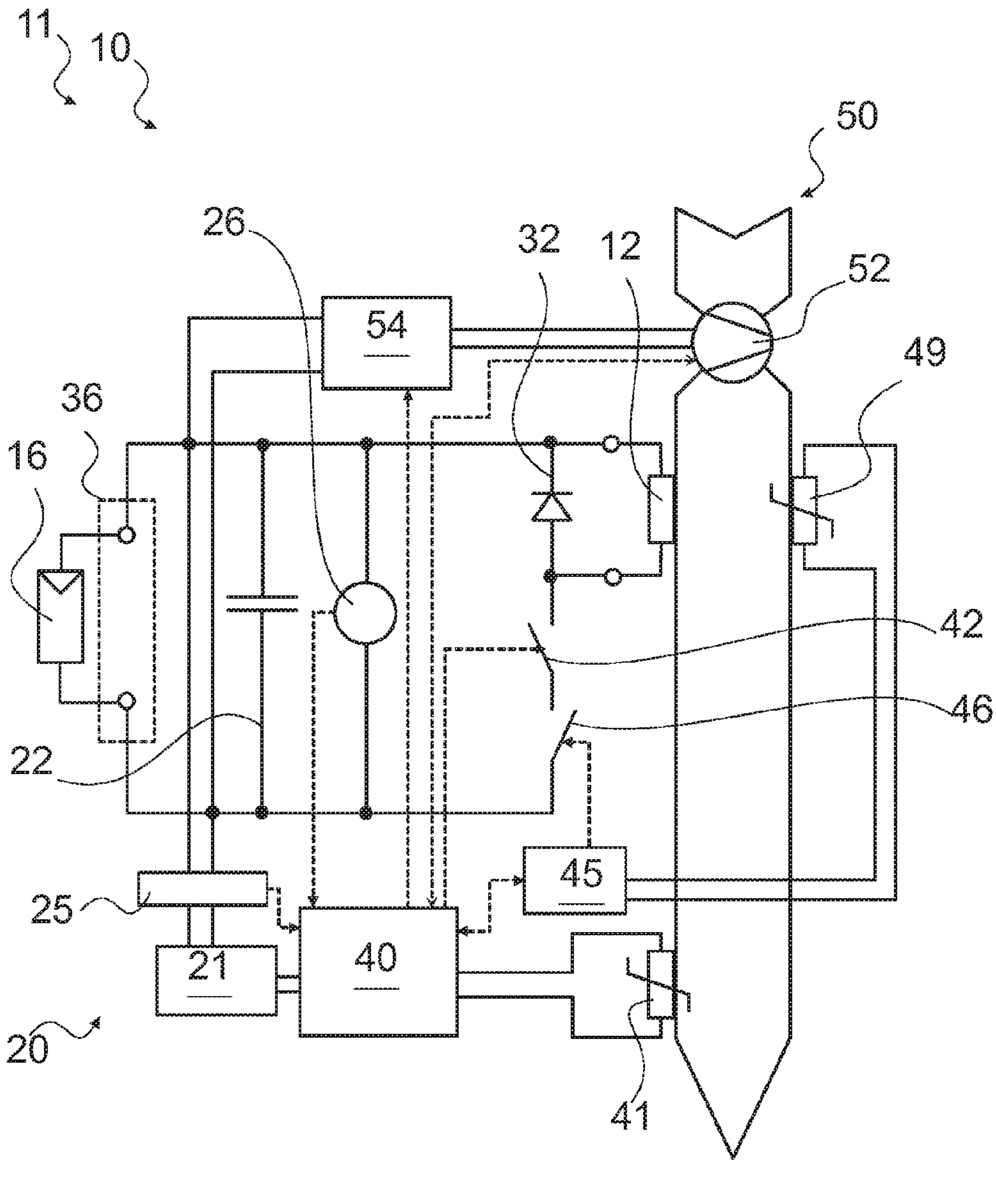


Fig. 1

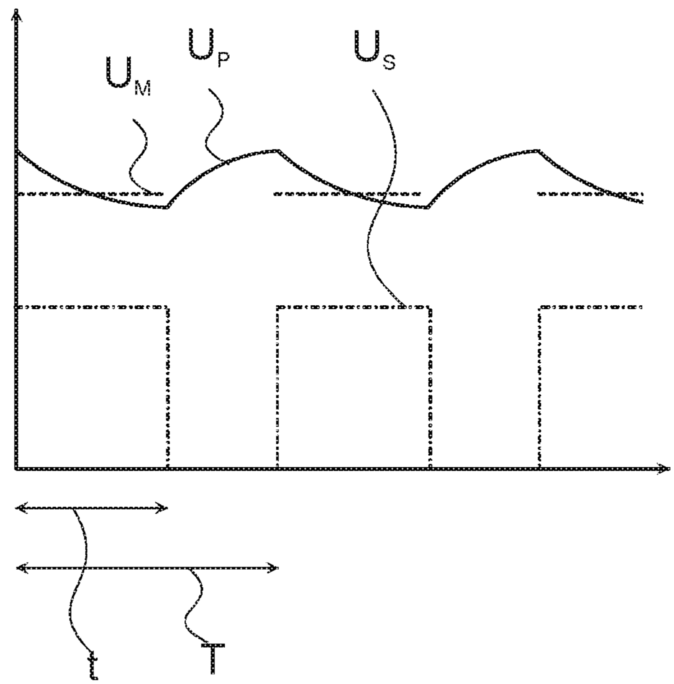


Fig. 2

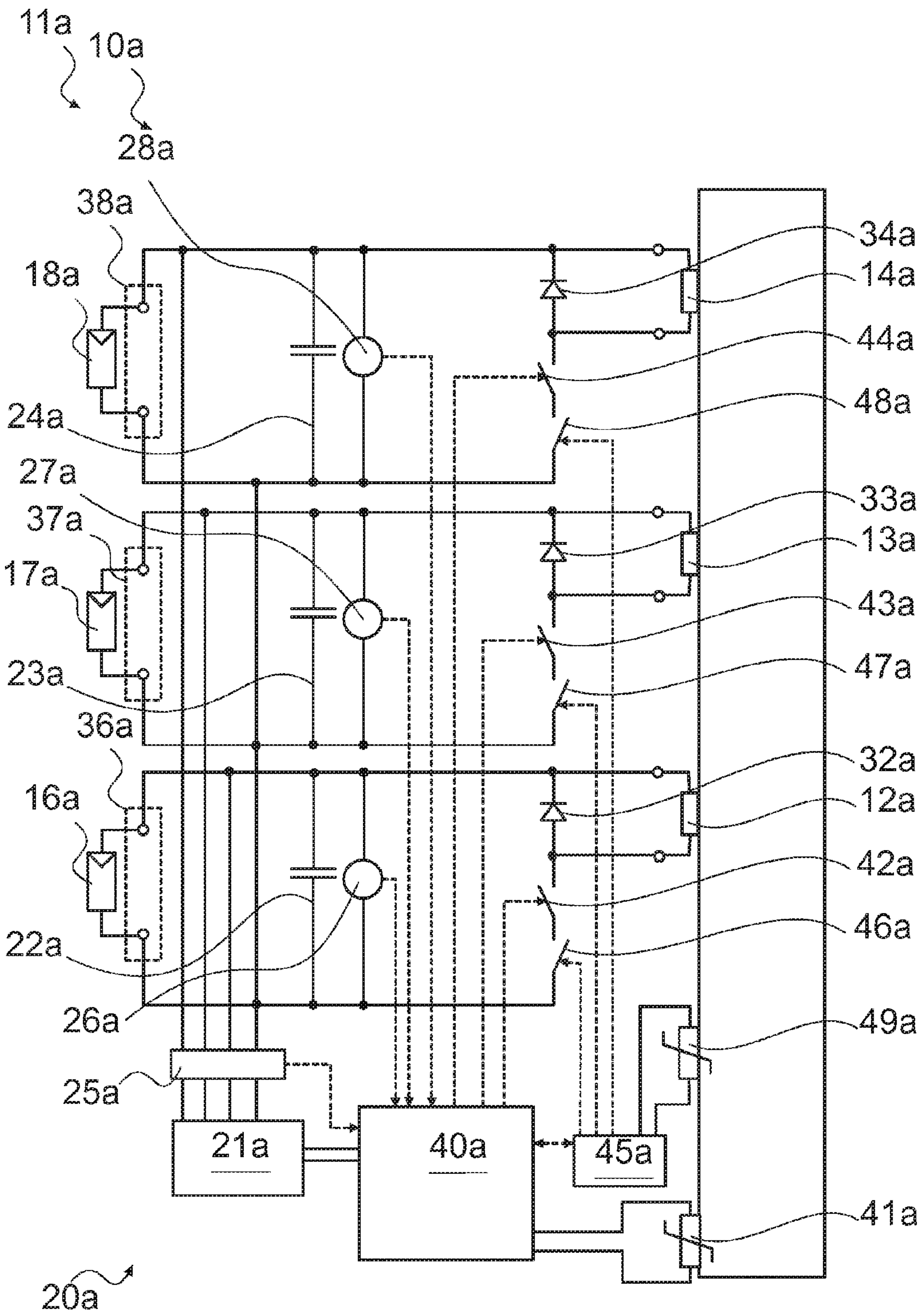

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Fig. 3

HEATING DEVICE

STATE OF THE ART

[0001] The invention relates to a heating device according to the preamble of claim **1**.

[0002] Usage of photovoltaic plants for heating has already been proposed.

[0003] The objective of the invention is, in particular, to make a generic device available, having improved characteristics regarding a high efficiency and/or low costs. The objective is achieved, according to the invention, by the features of patent claim **1**, while advantageous implementations and further developments of the invention may be retrieved from the subclaims.

ADVANTAGES OF THE INVENTION

[0004] The invention is based on a heating device, in particular for heating at least one fluid, with at least one first heating resistor and with at least one supply electronics unit, which is provided for supplying at least the first heating resistor with current provided by at least one first photovoltaic plant.

[0005] It is proposed that the supply electronics unit is provided for operating at least the first heating resistor in a clocked manner at least in one operating mode. A "fluid" is to be understood, in particular, as a liquid, a gas and/or a preferably at least pourable bulk good, in particular with particle sizes of maximally 5 cm, in particular no more than 3 cm, advantageously maximally 1 cm, preferably no more than 0.5 cm. As an alternative or additionally, it is conceivable that at least the first heating resistor is provided for heating a latent-heat storing material, which is in particular liquid in at least one operating state. It is furthermore conceivable that the heating resistor is provided for heating at least one solid body, in particular embodied as at least one rock and/or mineral block, in particular for heat storage. A "heating resistor" is to be understood, in particular, as a unit that is provided for converting electrical energy into heat to at least 70%, in particular to at least 90%, advantageously to at least 95%, preferably to at least 99%. In particular, the heating resistor is implemented by at least one electrical component, in particular by a group of electrical components, which are preferably connected permanently, in parallel and/or in series. In particular, at least one of the electrical components is implemented as a preferably metallic ohmic resistor. As an alternative or additionally, it is conceivable that the at least one of the electrical components is implemented as a semiconductor component with an in particular controllable resistance. In particular, the at least one electrical component of the heating resistor is encompassed by an in particular metallic, preferably tube-shaped sleeve body, which is advantageously provided for establishing a thermal contact between the heating resistor and the medium that is to be heated, in particular the fluid, in particular via heat conduction and/or heat radiation. In particular, the heating resistor implements a coil heating apparatus. In particular, between the electrical component and the sleeve body at least one electrically isolating, advantageously highly thermally conductive, preferably ceramic material is arranged. In particular, at least one of the electrical components is wound around a ceramic carrier, which is inserted into a sleeve body which forms a border against the medium that is to be heated and is embodied as a hollow body, wherein an air gap is retained between the electrical component and the sleeve body, as a result of which heat transfer takes places substantially via heat radiation. In particular, the heating device comprises a fluid container and/or a fluid conducting element, into which the heating resistor protrudes and/or which is passed through by the heating resistor. As an alternative, it is conceivable that the heating resistor forms a wall of the fluid container and/or fluid conducting element. In particular, the supply electronics unit comprises at least one power interface, which is provided to be connected to the photovoltaic plant. Preferably the supply electronics unit comprises at least one control unit, which is provided at least for controlling and/or regulating an operation of the heating resistor. By a "photovoltaic plant" in particular a unit is to be understood, which is provided for converting light, in particular sunlight, directly into electrical energy. In particular, a photovoltaic plant is embodied merely by photovoltaic cells, protecting sleeves, carrier elements and/or connecting cables. By a "clocked operation" is to be understood, in particular, an operating mode in which the heating resistor is repeatedly connected to the photovoltaic plant at a frequency of more than 100 Hz, in particular more than 1 kHz, advantageously more than 10 kHz, preferably more than 20 kHz, and/or at a frequency of maximally 100 kHz, in particular no more than 60 kHz, advantageously maximally 40 kHz, in particular periodically. In particular, the supply electronics unit comprises at least one switching element, which is arranged in a series connection circuit with the photovoltaic plant and the heating resistor, and is advantageously controlled by the control unit for generating the clocked operation, and is in particular implemented as a semiconductor switching element, preferably as a power MOSFET and/or power IGBT, alternatively as an electro-mechanical switching element, in particular as a relay. Preferentially the supply electronics unit additionally comprises at least one operating mode in which the heating resistor is continuously connected to the photovoltaic plant. "Provided" is to mean, in particular, specifically programmed, designed and/or equipped. By an object being provided for a certain function is to be understood, in particular, that the object fulfills and/or carries out said certain function in at least one application state and/or operating state. In particular, a high level of efficiency and/or low costs are achievable, in particular due to saving components.

[0006] It is also proposed that the supply electronics unit is provided for operating at least the first heating resistor in at least one operating mode at a frequency between 1 kHz and 100 kHz, in particular at a frequency between 10 kHz and 70 kHz, advantageously at a frequency between 20 kHz and 50 kHz, preferably at a frequency between 30 kHz and 40 kHz. In particular, a high level of efficiency is achievable. In particular, low switching loss is achievable at a substantially constant load on the photovoltaic plant. In particular, a cost-competitive and/or simple implementation can be achieved with a small number of components.

[0007] Furthermore it is proposed that the supply electronics unit is provided for adapting a duty cycle of the clocked operation at least of the first heating resistor for setting a power dropping across the heating resistor. A "duty cycle of the clocked operation" is to mean, in particular, a duty cycle of a control signal, in particular of a control voltage, by means of which the control unit controls the switching element for the purpose of connecting the heating resistor to the photovoltaic plant. In particular, a simple controlling is achievable.

[0008] It is further proposed that the supply electronics unit is provided for varying a duty cycle of the clocked operation at least of the first heating resistor for the purpose of optimizing the power dropping across the first heating resistor. In particular, the supply electronics unit comprises at least one voltage control loop, the voltage control loop being advantageously provided for converting a voltage difference between a given nominal voltage and a measured actual voltage into a duty cycle of the clocked operation. In particular, the supply electronics unit is provided for modifying in one variation step, in regular and/or irregular intervals, the nominal voltage and/or the duty cycle of the clocked operation by a certain amount and to compare a resulting power output via the heating resistor to a value measured previous to the modification, wherein the nominal voltage and/or the duty cycle that results in a higher power output is continued. In particular, in one variation step the nominal voltage is increased and/or the duty cycle is reduced if in the previous variation step a power increase could be achieved by increasing the nominal voltage and/or reducing the duty cycle, or if no power increase could be achieved by reducing the nominal voltage and/or increasing the duty cycle. In particular, in one variation step the nominal voltage is reduced and/or the duty cycle is increased if in the previous variation step a power increase could be achieved by reducing the nominal voltage and/or by increasing the duty cycle, or if no power increase could be achieved by increasing the nominal voltage and/or reducing the duty cycle. Advantageously the control unit is provided for setting a variation of the nominal voltage and/or of the duty cycle if the power output reaches a nominal power of the heating resistor until the power output drops below the nominal power. In particular, a simple controlling is achievable. As an alternative, implementations are conceivable in which an ideal nominal voltage and/or an ideal duty cycle is calculated at least on the basis of measured voltage parameters and current parameters of the current of the photovoltaic plant, and/or on the basis of other measured parameters that are deemed suitable by a person having ordinary skill in the art, or implementations in which an alternative variation method is applied that is deemed suitable by a person having ordinary skill in the art.

[0009] Moreover it is proposed that the supply electronics unit comprises at least one buffering capacity that is allocated to the first heating resistor and is provided for at least intermediately storing energy of the photovoltaic plant. In particular, the buffering capacity is embodied by at least one capacitor. In particular, a high level of efficiency is achievable as energy supplied by the photovoltaic plant can be utilized in states in which the heating resistor is not connected to the photovoltaic plant for a short period. In particular, a high energy yield is achievable.

[0010] It is further proposed that the supply electronics unit is provided for measuring, in particular measuring nothing but, a voltage over the buffering capacity to determine a power outputted via the heating resistor. In particular, the supply electronics unit comprises at least one voltage sensor, which measures a voltage dropping across the buffering capacity. In particular, the control unit is provided for calculating a power outputted in the heating resistor depending on at least one voltage measurement value, in particular of a voltage characteristic over the buffering capacity in particular only while the heating resistor is connected to the photovoltaic plant, of the known duty cycle of the clocked operation and of an at least substantially known value of the ohmic resistance of the heating resistor. In particular, a saving of components, a low measuring effort and/or a high efficiency can be achieved. As an alternative, it is conceivable that the supply electronics unit is provided for, in particular nothing but, measuring a current through the heating resistor.

[0011] Advantageously the supply electronics unit is provided for selecting the duty cycle of the clocked operation at least depending on an average voltage applied at the buffering capacity, in particular depending on a power output calculated on the basis of this average voltage. An "average voltage" is to mean, in particular, a voltage averaged, in particular quadratically averaged, over a period in which the heating resistor is connected to the photovoltaic plant. In particular, an improved measuring accuracy is achievable. In particular, components can be saved, in particular at least a current sensor for measuring a current through the heating resistor can be dispensed with.

[0012] Advantageously the heating resistor is directly connected to a buffering capacity of the supply electronics unit. By the heating resistor being "directly" connected to the buffering capacity is to be understood, in particular, that at least in a state in which the heating resistor is connected to the photovoltaic plant, the heating resistor is connected in series with the buffering capacity merely via at least substantially purely ohmic elements, in particular merely electrical connection lines and/or switching elements. In particular, a high level of efficiency and/or considerable saving of components can be achieved as, in particular, additional converter stages are dispensed with.

[0013] The buffering capacity is advantageously provided for being directly connected to the photovoltaic plant. In particular, merely at least substantially ohmic elements, in particular merely electrical connection lines and/or switching elements, are connected in series with the buffering capacity between the power interface for connecting the photovoltaic plant and the buffering capacity. A high level of efficiency and/or considerable saving of components can be achieved as, in particular, additional converter stages are dispensed with.

[0014] It is also proposed that the supply electronics unit is provided for varying a frequency of the clocked operation in at least one operating mode. The supply electronics unit is, in particular, provided for varying the frequency of the clocked operation depending on a power retrievable from the photovoltaic plant. In particular, the supply electronics unit is provided, in an operating state in which a power outputted via the heating resistor corresponds to maximally 50%, in particular no more than 30%, advantageously maximally 20%, preferentially no more than 10% of a nominal power of the heating resistor, to reduce, in particular to a half, a third and/or a quarter, advantageously in a staggered fashion, a frequency of the clocked operation that is usually applied for a power above 50% of the nominal power. In particular, a high degree of efficiency is achievable as in particular switching losses can be reduced. Moreover it is proposed that the supply electronics unit is provided for modifying a frequency of the clocked operation in a range having a width of at least 1 kHz, in particular at least 3 kHz, advantageously at least 8 kHz and/or in a range having a width of maximally 20 kHz, advantageously no more than 13 kHz, in particular in a periodical and/or linear fashion, as an alternative in an erratic and/or random fashion, for the purpose of reducing a harmonic wave spectrum, in particular a harmonic wave spectrum that is radiated off and/or re-transferred into the photovoltaic plant.

[0015] It is also proposed that the supply electronics unit comprises at least one sensor unit, which is provided for analyzing a frequency of a current retrieved from the photovoltaic plant for the purpose of deducing a behavior typical for an electric arc. In particular, the sensor unit is embodied by the voltage sensor that is provided for power determination, wherein the control electronics unit is in particular provided for filtering an actual frequency of the clocked operation from the measured signal of the voltage sensor. As an alternative, it is conceivable that the supply electronics unit comprises an additional sensor, in particular a current sensor for measuring a current over the power interface, for the purpose of achieving an improved measuring accuracy. In particular, a frequency between 10 kHz and 30 kHz which differs from a frequency of the clocked operation, indicates a behavior typical for an electric arc, in which arcs occur at connection contacts of the photovoltaic plant, in particular of the photovoltaic cells, said connection contacts being in particular embodied as plug contacts. The supply electronics unit is in particular provided for at least shortly interrupting an operation of the heating resistor in case a behavior typical for an electric arc is detected, for the purpose of extinguishing the arc and/or at least emitting a warning message. In particular, the supply electronics unit is provided for stopping an operation until maintenance measures have been completed, at least in case of a repeatedly occurring behavior typical for an electric arc. In particular, a high degree of safety and/or a long service life of the connected photovoltaic plant can be achieved.

[0016] Advantageously it is proposed that the supply electronics unit comprises at least one temperature sensor. Preferentially the temperature sensor is arranged at least near the medium that is to be heated, advantageously in such a way that it is encompassed by the medium that is to be heated. In particular, the temperature sensor is integrated in a sleeve of the heating resistor. As an alternative or additionally, it is conceivable that the temperature sensor is located separately. In particular, enhanced safety is achievable. In particular, the supply electronics unit is provided for at least reducing and/or terminating an operation at least of the first heating resistor in case of a limit temperature being exceeded, via the temperature sensor. Enhanced safety is in particular achievable. In particular, a high degree of comfort is achievable.

[0017] Furthermore it is proposed that the heating device comprises at least one fluid transport unit, which is provided for conveying a fluid that is to be heated past the heating resistor and which is controlled and/or supplied by the supply electronics unit, in particular in dependency of the temperature sensor. In particular, the fluid transport unit is provided for feeding a fluid to the heating resistor. In particular, the fluid transport unit is provided for enforcing a movement of a fluid. In particular, the fluid transport unit comprises at least a pump, a ventilator and/or a screw conveyor. In particular, the supply electronics unit is provided for regulating a delivery volume of the fluid transport unit in such a way that a temperature measured by the temperature sensor is kept at least substantially constant and/or corresponds to a value which is, in particular, set by an operator. In particular, the supply electronics unit comprises at least one voltage converter and/or frequency converter, which is provided for converting energy supplied by the photovoltaic plant into a form required by the fluid transport unit. As an alternative, it is conceivable that the fluid transport unit is supplied via a separate grid connection, wherein the fluid transport unit preferably comprises at least one regulation interface via which the control unit of the supply electronics unit can set a delivery volume and/or delivery speed. In particular, a high quality is achievable.

[0018] It is moreover proposed that the supply electronics unit comprises a supervising unit, which is provided for monitoring at least a serviceability of a control unit that controls the clocked operation at least of the one heating resistor. In particular, the supervising unit comprises at least one separate temperature sensor and is provided for, preferably redundantly, interrupting a connection between the heating resistor and the photovoltaic plant in case a limit temperature is exceeded. An overheating may be caused in particular by a misfunction of the control unit, a misfunction of a first sensor and/or a misfunction of a switching element. In particular, the supervising unit comprises a separate switching element, which is connected in series between the heating resistor and the power interface. In particular, the supervising unit and the control unit each comprise at least one communication inlet for implementing at least a serviceability of the control unit. Preferably the control unit is provided for carrying out a serviceability of the supervising unit via the communication inlets. In particular, the control unit and the supervising unit are together provided for allowing a current flow through the heating resistor only if a serviceability of both units has been ensured. In particular, a high degree of safety is achievable, in particular against overheating and/or subsequent damages.

[0019] It is further proposed that a control electronics unit of the supply electronics unit is provided for being supplied by the photovoltaic plant. In particular, the supply electronics unit comprises at least one voltage and/or frequency converter, which is provided for converting energy supplied by the photovoltaic plant into a form that is required by the control electronics unit, in particular at least the control unit, the supervising unit and/or the at least one sensor. In particular, a high level of self-sufficiency is achievable, as the control electronics unit is, in particular, only active if a sufficient amount of energy is available.

DRAWINGS

[0020] Further advantages may be gathered from the following description of the drawings. In the drawings, two exemplary embodiments of the invention are shown. The drawings, the description and the claims contain a plurality of features in combination. The person skilled in the art will purposefully consider the features separately and will find further expedient combinations.

[0021] It is shown in:

[0022] FIG. **1** a heating device according to the invention for generating a fluid flow with a constant temperature,

[0023] FIG. **2** an exemplary process of a clocked operation, and

[0024] FIG. **3** an alternative heating device according to the invention provided to be connected to a plurality of photovoltaic plants.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0025] FIG. **1** shows a system **11** with a heating device **10** and with a first photovoltaic plant **16**.

[0026] The heating device **10** is provided for heating and drying a fluid that is embodied as a bulk good, and comprises a first heating resistor **12** and a supply electronics unit **20**, which is provided for supplying the first heating resistor **12** with current provided by the first photovoltaic plant **16**. The supply electronics unit **20** is provided for operating the first heating resistor **12** in a clocked manner in different operating modes.

[0027] The supply electronics unit **20** comprises a buffering capacity **22** that is allocated to the first heating resistor **12** and is provided for intermediary storage of energy from the photovoltaic plant **16**. The supply electronics unit **20** comprises a first power interface **36**, which is connected to the photovoltaic plant **16**. The buffering capacity **22** is provided for being directly connected to the photovoltaic plant **16**. The buffering capacity **22** is directly connected to the power interface **36**. The heating resistor **12** is directly connected to the buffering capacity **22** of the supply electronics unit **20**.

[0028] The supply electronics unit **20** further comprises an insulation measuring unit **25**, which is provided for determining whether the photovoltaic plant **16** is operated in a grounded or an un-grounded configuration. The insulation measuring unit **25** is connected between the poles of the power interface **36**. The insulation unit **25** comprises a voltage divider, which works in a first state such that it divides the voltage in halves and works in a second state such that it divides the voltage asymmetrically, a voltage being measured at the center tap of the voltage divider across a high-ohmic resistor with respect to the ground potential. If measuring shows in both states too low bleeder resistances, a warning message is emitted.

[0029] The supply electronics unit **20** comprises a control unit **40**, which controls and regulates an operation of the heating resistor **12**. The supply electronics unit **20** comprises a first switching element **42**, which is embodied as a semiconductor switching element and is arranged in series with the heating resistor **12** and the buffering capacity **22** and thus the photovoltaic plant **16**. The supply electronics unit **20** comprises a flyback diode **32**, which is provided for discharging voltages and currents which occur with release of the connection with the photovoltaic plant **16** and are generated by possibly existing self-inductances of the heating resistor **12** or of its connection lines. The supply electronics unit **20** comprises a voltage sensor **26** measuring a voltage Up across the buffering capacity **22**.

[0030] The supply electronics unit **20** comprises a supervising unit **45**, which is provided for monitoring at least a serviceability of the control unit **40**. The supervising unit **45** comprises a first temperature sensor **49**. The temperature sensor **49** is provided for measuring a temperature of the fluid in a proximity range of the heating resistor **12**. The supervising unit **45** is provided for terminating an operation of the first heating resistor **12** in case of a limit temperature being exceeded, via the first temperature sensor **49**, which is arranged in a proximity range of the first heating resistor **12**. The supervising unit **45** comprises a second switching element **46**, which is provided for interrupting a connection between the heating resistor **12** and the photovoltaic plant **16**, respectively the buffering capacity **22**. The second switching element **46** is arranged in series with the heating resistor **12** and the buffering capacity **22**, respectively the photovoltaic plant **16**. If the supervising unit **45** states a serviceability of the control unit **40** and detects, via the first temperature sensor **49**, a temperature below the limit temperature, the supervising unit **45** initiates a switching of the second switching element **46**, as a result of which there is nothing to prevent a connection of the heating resistor **12** to the photovoltaic plant **16**. The second switching element **46** is embodied as a relay but could, as an alternative, also be embodied as a semiconductor switching element. Moreover it is conceivable, as an alternative, that the second switching element is provided for interrupting a control signal U_S of the first switching element.

[0031] The control unit **40** comprises a second temperature sensor **41**. Furthermore the heating device **10** comprises a fluid transport unit **50**, which is provided for conveying a fluid that is to be heated past the heating resistor **12** and which is controlled and supplied by the supply electronics unit **20**. A delivery volume of the fluid transport unit **50** is regulated by the control unit **40** in such a way that a temperature measured by the second temperature sensor **41**, which is arranged—viewed in a transport direction—downstream of the heating resistor **12**, remains constantly at a preset value. The fluid transport unit **50** comprises a drive unit **52** embodied as a screw conveyor for transporting the fluid. The supply electronics unit **20** comprises a voltage converter **54**, which is provided for supplying the drive unit **52** from the photovoltaic plant **16**. The control electronics unit, i.e.

[0032] the control unit **40**, the supervising unit **45**, the temperature sensors **41**, **49** and the voltage sensor **26**, is supplied by the photovoltaic plant **16** via a voltage converter **21** of the supply electronics unit **20**. In an alternative implementation it is conceivable that the drive unit is embodied as a conveyor belt and the heating resistor is embodied, for example, as a radiator arranged above the conveyor belt. However, implementations as a continuous-flow heater for liquids, in particular water, are conceivable as well.

[0033] If the control unit **40** states a serviceability of the supervising unit **45**, the control unit **40** generates a control signal U_S for controlling the first switching element **42**. A duty cycle t/T of the control signal U_S is herein determined iteratively.

[0034] The supply electronics unit **20** determines, on the basis of the voltages Up measured via the voltage sensor **26** over the buffering capacity **22** during a connection phase t of a total interval T, an average voltage U_M (FIG. **2**). A power P dropping across the heating resistor **12** is then calculated by the control unit **40** according to

$$P=(U_M^2/R)*(t/T),$$

wherein R corresponds to the ohmic resistance of the heating resistor **12**. The supply electronics unit **20** is provided for adapting a duty cycle t/T of the clocked operation of the first heating resistor **12** for the purpose of setting a power P dropping across the heating resistor **12**. The duty cycle t/T of the clocked operation is herein indirectly varied via variation of a nominal voltage of a voltage regulator provided for regulating a voltage applied at the buffering capacity **22** and/or the power interface **36** to a nominal voltage, for the purpose of maximizing the dropping power P. Should an available power exceed the nominal power, the duty cycle t/T is reduced in such a way that the nominal power is achieved at a maximally possible duty cycle. The duty cycle t/T is thus selected depending on an average voltage Um applied over the buffering capacity **22**.

[0035] The supply electronics unit **20** is provided for operating the heating resistor **12** in a clocked manner in an operating mode in which a power retrievable from the photovoltaic plant **16** amounts to at least 10% of a nominal power of the heating resistor **12**, at a frequency varying between 30 kHz and 50 kHz. In operating modes in which the retrievable power drops below 10% of the nominal power, the supply electronics unit **20** is provided for operating the heating resistor **12** in a clocked manner at a frequency varying between 15 kHz and 25 kHz. In an operating mode in which a retrievable power amounts to approximately 100% of the nominal power, the supply electronics unit **20** is provided for operating the heating resistor **12** continuously.

[0036] The voltage sensor **26** is used by the supply electronics unit **20** for analyzing a frequency of the current retrieved from the photovoltaic plant **16**. Herein the signal of the voltage sensor **26** is corrected by filtering the actual frequency of the clocked operation. If there are still dominant frequencies left in a range between 10 kHz and 30 kHz, a behavior typical for an electric arc of the photovoltaic plant **16** is deduced and an operation of the heating resistor **12** is interrupted for some seconds.

[0037] In FIG. **3** a further exemplary embodiment of the invention is shown. The following descriptions and the drawing are substantially limited to the differences between the exemplary embodiments, wherein principally the drawings and/or the description of the other exemplary embodiments, in particular FIGS. **1** and **2**, may be referred to in particular as regards structural components having the same reference numerals. For the purpose of distinguishing the exemplary embodiments, the letter a is added to the reference numerals of the exemplary embodiment in FIG. **3**.

[0038] FIG. **3** shows a system **11** a with a heating device **10***a* and a first, a second and a third photovoltaic plant **16***a*, **17***a*, **18***a*. The heating device **10***a* is embodied as a hot-water boiler and comprises for heating water a first heating resistor **12***a*, a second heating resistor **13***a* and a third heating resistor **14***a*. The heating device **10***a* comprises a supply electronics unit **20***a*, which is provided for respectively supplying the heating resistors **12***a*, **13***a*, **14***a* with current and voltage provided by precisely one of the photovoltaic plants **16***a*, **17***a*, **18***a*. The supply electronics unit **20***a* is provided for operating the heating resistors **12***a*, **13***a*, **14***a* in a clocked manner in a plurality of operating modes.

[0039] For each of the heating resistors **12***a*, **13***a*, **14***a* the supply electronics unit **20***a* comprises a separate buffering capacity **22***a*, **23***a*, **24***a*, to which the respective heating resistor **12***a*, **13***a*, **14***a* is directly connected. Furthermore, the supply electronics unit **20***a* comprises three power interfaces **36***a*, **37***a*, **38***a*, which are respectively provided for being connected to one of the photovoltaic plants **16***a*, **17***a*, **18***a* and which are respectively connected directly with a respective allocated buffering capacity **22***a*, **23***a*, **24***a*, as a result of which the buffering capacities **22***a*, **23***a*, **24***a* implement an intermediary storage of energy from the respective photovoltaic plant **16***a*, **17***a*, **18***a*. The power interfaces **36***a*, **37***a*, **38***a* have a shared contact. The supply electronics unit **20***a* comprises voltage sensors **26***a*, **27***a*, **28***a* allocated to the respective buffering capacities **22***a*, **23***a*, **24***a*.

[0040] For the purpose of avoiding noise emissions, the heating resistors **12***a*, **13***a*, **14***a* are operated at an identical frequency. For setting powers dropping across the heating resistors **12***a*, **13***a*, **14***a*, duty cycles of the clocked operations of the heating resistors **12***a*, **13***a*, **14***a* are varied separately to achieve a maximization of the powers dropping across the respective heating resistors **12***a*, **13***a*, **14***a*. The heating resistors **12***a*, **13***a*, **14***a* serve to heat fluid or solid matter in a single container.

[0041] The supply electronics unit **20***a* comprises a supervising unit **45***a*, which is provided for monitoring at least a serviceability of a control unit **40***a* that controls the clocked operation of the heating resistors **12***a*, **13***a*, **14***a*.

[0042] The control unit **40***a* comprises a first temperature sensor **41***a*. The first temperature sensor **41***a* serves to monitor a temperature of the fluid and/or the solid matter in the container. The control unit **40***a* is provided for terminating or at least reducing an operation of the heating resistors **12***a*, **13***a*, **14***a* in case of a first limit temperature being exceeded, via the first temperature sensor **41***a*. The supervising unit **45***a* comprises a second temperature sensor **49***a*. The second temperature sensor **49***a* also serves to monitor a temperature of the fluid and/or the solid matter in the container. The supervising unit **45***a* is provided for terminating an operation of the heating resistors **12***a*, **13***a*, **14***a* in case of a second limit temperature, which is slightly higher than the first limit temperature, being exceeded, via the second temperature sensor **49***a*.

[0043] The supply electronics unit **20***a* comprises a first, a third and a fifth switching element **42***a*, **43***a*, **44***a*, which are respectively arranged in series with precisely one of the heating resistors **12***a*, **13***a*, **14***a* and with precisely one of the buffering capacities **22***a*, **23***a*, **24***a* and thus with precisely one of the photovoltaic plants **16***a*, **17***a*, **18***a*. Each of the first, third and fifth switching elements **42***a*, **43***a*, **44***a* is respectively embodied as a MOSFET or an

[0044] IGBT. The first, third and fifth switching elements **42***a*, **43***a*, **44***a* are controlled by the control unit **40***a* with clocked control signals at frequencies between 15 kHz and 50 kHz for operating the heating resistors **12***a*, **13***a*, **14***a* in a clocked manner. A flyback diode **32***a*, **33***a*, **34***a* is connected in parallel to each of the heating resistors **12***a*, **13***a*, **14***a*.

[0045] The supervising unit **45***a* further comprises three switching elements **46***a*, **47***a*, **48***a*, which are respectively provided for avoiding an operation of the heating resistors **12***a*, **13***a*, **14***a* in case of an overheating detected by the second temperature sensor **49***a* or in case of a misfunction of the control unit **40***a* being detected. The second, fourth and sixth switching elements **46***a*, **47***a*, **48***a* are respectively arranged in series with precisely one of the heating resistors **12***a*, **13***a*, **14***a* and with precisely one of the buffering capacities **22***a*, **23***a*, **24***a* and thus with precisely one of the photovoltaic plants **16***a*, **17***a*, **18***a*.

[0046] As an alternative, implementations with different numbers of heating resistors and/or photovoltaic plants are conceivable. It is further conceivable that the supervising unit comprises only one single switching element, which is arranged in series with respect to all heating resistors and to each of the first, third and fifth switching elements.

[0047] There are moreover implementations conceivable, in which a plurality of heating resistors can be connected in series with each other selectively, adapted to an available power, and in which this selection of heating resistors that are connected in series can be connected to one or several photovoltaic plants that are connected in parallel, as a result of which an increased efficiency is achievable, in particular due to reduced switching losses.

REFERENCE NUMERALS

[0048] **10** heating device
[0049] **11** system
[0050] **12** heating resistor
[0051] **13** heating resistor
[0052] **14** heating resistor
[0053] **16** photovoltaic plant

[0054] **17** photovoltaic plant
[0055] **18** photovoltaic plant
[0056] **20** supply electronics unit
[0057] **21** voltage converter
[0058] **22** buffering capacity
[0059] **23** buffering capacity
[0060] **24** buffering capacity
[0061] **25** insulation measuring unit
[0062] **26** voltage sensor
[0063] **27** voltage sensor
[0064] **28** voltage sensor
[0065] **32** flyback diode
[0066] **33** flyback diode
[0067] **34** flyback diode
[0068] **36** power interface
[0069] **37** power interface
[0070] **38** power interface
[0071] **40** control unit
[0072] **41** temperature sensor
[0073] **42** switching element
[0074] **43** switching element
[0075] **44** switching element
[0076] **45** supervising unit
[0077] **46** switching element
[0078] **47** switching element
[0079] **48** switching element
[0080] **49** temperature sensor
[0081] **50** fluid transport unit
[0082] **52** drive unit
[0083] **54** voltage converter
[0084] T total interval
[0085] U_M average voltage
[0086] U_P voltage
[0087] U_S control signal
[0088] t connection phase

1. A heating device, in particular for heating at least one fluid, with at least one first heating resistor and with at least one supply electronics unit, which is provided for supplying at least the first heating resistor with current provided by at least one first photovoltaic plant, wherein the supply electronics unit is provided for operating at least the first heating resistor in a clocked manner at least in one operating mode.

2. The heating device according to claim **1**, wherein the supply electronics unit is provided for operating at least the first heating resistor at a frequency between 1 kHz and 100 kHz in at least one operating mode.

3. The heating device according to claim **1**, wherein the supply electronics unit is provided for adapting a duty cycle of the clocked operation for setting a power dropping across the heating resistor.

4. The heating device according to claim **3**, wherein the supply electronics unit is provided for varying a duty cycle of the clocked operation at least of the first heating resistor for optimizing the power dropping across the first heating resistor.

5. The heating device according to one of the preceding claim **1**, wherein the supply electronics unit comprises at least one buffering capacity that is allocated to the first heating resistor and is provided for an at least intermediary storage of energy from the photovoltaic plant.

6. The heating device according to claim **5**, wherein the supply electronics unit is provided for measuring a voltage over the buffering capacity to determine a power dropping across the heating resistor.

7. The heating device according to claim **4**, wherein the supply electronics unit is provided for selecting the duty cycle of the clocked operation at least depending on an average voltage applied at the buffering capacity.

8. The heating device according to claim **5**, wherein the heating resistor is directly connected to a buffering capacity of the supply electronics unit.

9. The heating device according to claim **5**, wherein the buffering capacity is provided for being directly connected to the photovoltaic plant.

10. The heating device according to claim **1**, wherein the supply electronics unit is provided for varying a frequency of the clocked operation.

11. The heating device according to claim **10**, wherein the supply electronics unit is provided for varying the frequency of the clocked operation depending on a power retrievable from the photovoltaic plant.

12. The heating device according to claim **1**, wherein the supply electronics unit comprises at least one sensor unit, which is provided for analyzing a frequency of a current retrieved from the photovoltaic plant for the purpose of deducing a behavior typical for an electric arc.

13. The heating device according to claim **1**, wherein the supply electronics unit comprises at least one temperature sensor.

14. The heating device according to claim **13**, wherein the supply electronics unit is provided for at least reducing an operation at least of the first heating resistor in case a limit temperature is exceeded, via the temperature sensor.

15. The heating device according to claim **13**, comprising a fluid transport unit, which is provided for conveying a fluid that is to be heated past the heating resistor and which is controlled and/or supplied by the supply electronics unit.

16. The heating device according to claim **1**, wherein the supply electronics unit comprises a supervising unit, which is provided for monitoring at least a serviceability of a control unit that controls the clocked operation at least of the one heating resistor.

17. The heating device according to claim **1**, wherein an control electronics unit of the supply electronics unit is provided for being supplied by the photovoltaic plant.

18. A method for operating a heating device according to claim **1**.

19. A system with a photovoltaic plant and with a heating device according to claim **1**.

20. The heating device according to claim **2**, wherein the supply electronics unit is provided for adapting a duty cycle of the clocked operation for setting a power dropping across the heating resistor.

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