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

(11) EP 4 249 642 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.09.2023 Bulletin 2023/39

(21) Application number: **22163339.9**

(22) Date of filing: **21.03.2022**

(51) International Patent Classification (IPC):
C25B 15/021 *(2021.01)* ***C25B 15/023*** *(2021.01)*

(52) Cooperative Patent Classification (CPC):
C25B 15/021; C25B 15/023

(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

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(54) ELECTROLYSIS METHOD AND ARRANGEMENT

(57) Method for performing an electrolysis with an electrolysis stack (1), wherein an electrolysis medium is used for the electrolysis that is cooled by means of a cooling medium provided at a flow rate F, wherein the flow rate F of the cooling medium is set to a value depending on a current value I_{cur} of a current density of the electrolysis stack (1) and a current value V_{cur} of a cell voltage of the electrolysis stack (1).

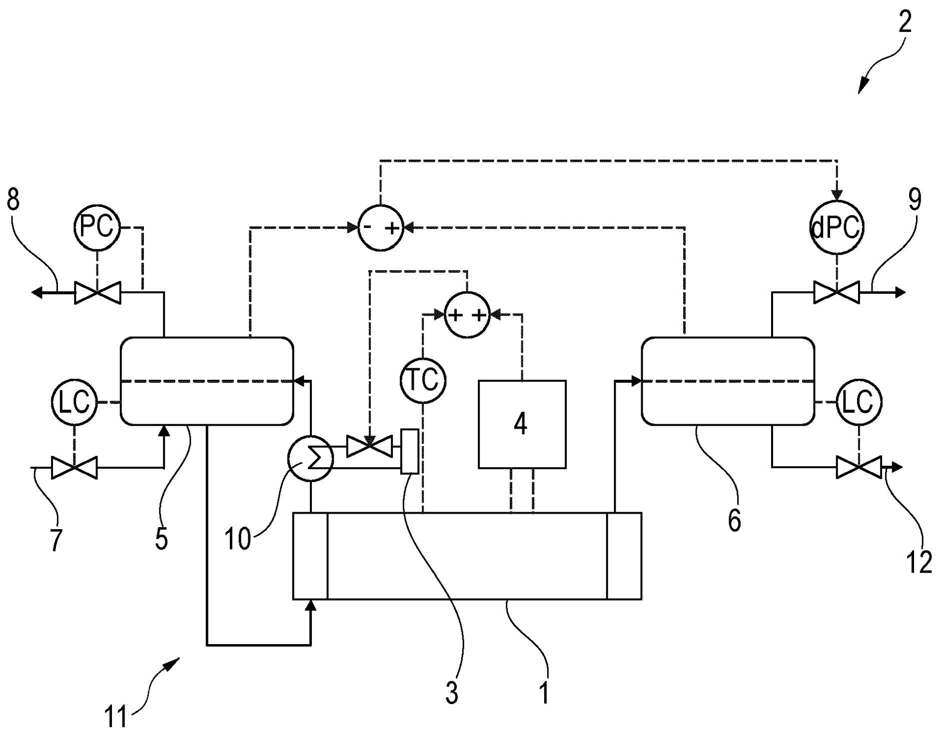

Fig. 1

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Description

[0001] The invention is directed to a method for performing an electrolysis as well as to a respective arrangement.

[0002] In known systems for the electrolysis of water, stacks of electrolysis cells are used that are supposed to be operated at a particular temperature. If the actual temperature deviates significantly from a temperature setting, the efficiency is reduced or the stacks may be damaged. Since the electrolysis in general generates heat, usually the electrolysis stack requires cooling in order to maintain the desired temperature.

[0003] It is known to control the temperature in that the temperature is measured and compared to a set point. In case the measured value deviates from the set point, a flow rate of a cooling medium is adapted. However, such a control loop is comparatively slow. This is particularly due to the fact that a change in the cooling medium flow rate will affect the temperature only with a delay. Also, such a temperature control is inaccurate.

[0004] Electrolysis is preferably performed using renewable energies. However, the availability of renewable energies such as solar and wind power fluctuates. Hence, it is desired that electrolysis systems are able to handle a fluctuating supply of electric energy. In particular to this end it is desired to have a temperature control that can react quickly to a change in the supply of electrical energy.

[0005] The object of the invention is to improve the prior art so that the temperature of an electrolysis process can be controlled particularly quickly and accurately.

[0006] The object is solved with the method and the arrangement according to the independent claims. Advantageous refinements are presented in the dependent claims. The features described in the claims and in the description can be combined with each other in any technologically reasonable manner.

[0007] According to the invention a method for performing an electrolysis with an electrolysis stack is presented, wherein an electrolysis medium is used for the electrolysis that is cooled by means of a cooling medium provided at a flow rate F, wherein the flow rate F of the cooling medium is set to a value depending on a current value I_{cur} of a current density of the electrolysis stack and a current value V_{cur} of a cell voltage of the electrolysis stack.

[0008] The electrolysis method can be used for electrolysis of any electrolysis medium. Preferably, the electrolysis medium is liquid, in particular water. In particular, the electrolysis medium can be water only. Alternatively, the electrolysis medium may be water that contains dissolved salts such as KOH for alkaline electrolysis or electrolysis using anion exchange membrane cells. The electrolysis products are preferably gaseous. In the case of water, hydrogen and oxygen can be obtained as the electrolysis products. The electrolysis method is intended to be used for an industrial scale electrolysis. For example, it is preferred that at least one of the electrolysis products is obtained at a rate of 250 to 1500 Nm^3 per hour per electrolysis stack. This applies, in particular, to the production of hydrogen in the case of water electrolysis. The electrolysis is preferably performed in an automated way.

[0009] The electrolysis method is performed using an electrolysis stack. That is, it is possible that the electrolysis method can be performed with one or more electrolysis stacks. Preferably, the electrolysis stacks each have a maximum rated DC power consumption in the range of 1 to 20 MW, in particular in the range of 3 to 10 MW. The described electrolysis method is preferably used for industrial scale electrolysis. In particular, this is to be understood in contrast to experimental setups on a laboratory scale. The industrial scale can be quantified in terms of the maximum rated DC power consumption of the electrolysis stack(s). The maximum rated DC power consumption is what is commonly used to describe electrolysis stacks. For example, a "5 MW electrolysis stack" has a maximum rated DC power consumption of 5 MW.

[0010] The electrolysis is performed with the electrolysis medium within the electrolysis stack. The electrolysis medium can be supplied to the electrolysis stack continuously, for example via a feed installation. In particular, the electrolysis medium can be circulated by means of the feed installation, in particular through the electrolysis stack and further elements such as a separator and/or a heat exchanger. That is, the electrolysis medium can enter the electrolysis stack, where the electrolysis is performed. Thereby, the electrolysis medium is converted into the electrolysis products. However, usually not the entire electrolysis medium present within the electrolysis stack reacts within the electrolysis stack. The remaining electrolysis medium can be guided out of the electrolysis stack. This remaining electrolysis medium is mixed with the electrolysis products. After having separated the electrolysis products from the electrolysis medium, for example within a separator, the electrolysis medium can be fed back to the electrolysis stack. To this end, the circle is closed. This is supposed to be understood such that there is a closed loop path, along which the electrolysis medium can flow, which involves the electrolysis stack. However, the electrolysis medium is continuously converted into the electrolysis products, such that there is a loss of electrolysis medium. In order to compensate for such losses and for potential other losses, the feed installation preferably comprises an inlet, via which new electrolysis medium can be introduced into the circulation. That is, a certain amount of the electrolysis medium introduced into the circulation via the inlet can pass the electrolysis stack one or several times, until this particular amount of the electrolysis medium is converted into the electrolysis products.

[0011] In one preferred embodiment the feed installation is configured as a single feed line. Alternatively, the feed installation can comprise multiple independent feed lines. Also, it is preferred that the feed installation comprises one or more separators. The feed installation can be part of a circuit, via which the electrolysis medium can be circulated. For example, the electrolysis medium together with an anode product of the electrolysis can be guided from the anode of the electrolysis stack to an anode separator, where the anode product can be separated from the electrolysis medium. The electrolysis medium together with a cathode product of the electrolysis can be guided from the cathode of the electrolysis stack to a cathode separator, where the cathode product can be separated from the electrolysis medium. From the separators the electrolysis medium can be guided back to the electrolysis stack via a feed line that, together with the separators, is part of the feed installation. In a further preferred embodiment the feed installation is configured as a feed line that has two branches, one of which being connected to an anode space or anode spaces of the electrolysis stack and the other one being connected to a cathode space or cathode spaces of the electrolysis stack. It is also possible that the feed installation comprises multiple feed line branches that merge into a single feed line. For example, a first of these branches can be connected to the anode separator and a second of these branches can be connected to the cathode separator. Downstream of where the branches merge the feed line can be connected to the electrolysis stack as a single line or as two branches.

[0012] It is preferred that the electrolysis is performed at a temperature in the range of 50 to 120°C, in particular of 90 °C. By means of the described method, this temperature can be controlled indirectly. To this end, the cooling medium is provided.

[0013] In a preferred embodiment of the method, the electrolysis medium is circulated through the electrolysis stack and a heat exchanger, wherein the electrolysis medium is cooled in the heat exchanger by means of a cooling medium provided to the heat exchanger at the flow rate F. However, although it is preferred that the electrolysis medium is circulated, the described method is also applicable in case the electrolysis medium is provided in the electrolysis stack in a stationary manner. In that case the electrolysis medium can be cooled by the cooling medium within the electrolysis stack. The cooling medium is fed at a flow rate such that the heating caused by the electrolysis and the cooling caused by the cooling medium result in a desired temperature of the electrolysis medium within the electrolysis stack.

[0014] In general, the electrolysis medium can be cooled by the cooling medium at any point upstream or within the electrolysis stack. This includes that the electrolysis medium can be cooled by the cooling medium at any point of the feed installation. It is sufficient that the electrolysis medium is cooled by the cooling medium at a point where the cooling impacts the electrolysis. That is, the cooling is performed prior or during the electrolysis. The feed installation can have an anode feed and a cathode feed that are separate from each other. In that case, the electrolysis medium can be cooled by the cooling medium in the anode feed and/or in the cathode feed. That is, it is sufficient to cool only the electrolysis medium that is fed to the anodes or to cool only the electrolysis medium that is fed to the cathodes. Also, the feed installation can have a joint feed for both anodes and cathodes.

[0015] The method can be applied to a single electrolysis stack. Alternatively, the method can be applied to multiple electrolysis stacks. In the latter case, the electrolysis medium can be fed to the electrolysis stacks using separate feed installations for the electrolysis stacks or using a common feed installation for all electrolysis stacks. In the case of separate feed installations, each electrolysis stack can be treated like the single electrolysis stack described exemplarily herein. In the case of a common feed installation the described method can be performed using parameters of one of the electrolysis stacks. To this end, this electrolysis stack is assumed to be representative of the other electrolysis stacks. Alternatively, the parameters of all the electrolysis stacks can be taken into account. For example, as the current value I_{cur} of the current density of the electrolysis stack a mean value of the current values I_{cur} of the current density of the electrolysis stacks can be used and as the a current value V_{cur} of the cell voltage of the electrolysis stack a mean value of the current values V_{cur} of the cell voltages of the electrolysis stacks can be used. The common feed installation can have, for example, a single heat exchanger via which the electrolysis medium can be cooled prior to being fed to the electrolysis stacks. In that case the flow rate F of the cooling medium is the flow rate at which the cooling medium is supplied to this heat exchanger.

[0016] In the case the electrolysis medium is circulated, the electrolysis medium is preferably circulated through the electrolysis stack and a heat exchanger. Therein, the electrolysis medium can be cooled within the heat exchanger. This occurs upstream of the electrolysis stack to the end that the electrolysis medium is guided from the heat exchanger back to the electrolysis stack.

[0017] It is preferred that the heat exchanger is integrated into a feed line that is part of the feed installation. In particular, it is preferred that the heat exchanger is integrated into a feed line that extends from an anode separator and/or from a cathode separator to the electrolysis stack. That is, the heat exchanger is preferably arranged between the anode separator and/or the cathode separator on the one hand and the electrolysis stack on the other hand. Alternatively, it is preferred that the heat exchanger is arranged within the anode separator and/or the cathode separator. There can be more than one heat exchanger. For example, separate feed lines for the anode and cathode can have a respective heat exchanger.

[0018] The cooling medium is provided to the heat exchanger at a flow rate F. The flow rate F of the cooling medium has an influence on the temperature of the electrolysis medium. In the case of a heat exchanger upstream of the electrolysis stack, the temperature of the electrolysis medium downstream of the heat exchanger can also depend on the temperature of the cooling medium and on the flow rate at which the electrolysis medium flows through the heat exchanger. The best results are thus obtained in the preferred case that the temperature of the cooling medium is constant and the electrolysis medium flows at a constant flow rate through the heat exchanger. However, it turns out that acceptable results can also be obtained if these conditions are not met. In particular, a minor deviation in cooling medium temperature and/or in flow rate of the electrolysis medium will only have a minor influence on the result. It was found that acceptable results can be achieved in particular in the preferred case that the temperature of the cooling medium does not fluctuate by more than 20 °C, in particular by not more than 10 °C, and/or that the electrolysis medium flows through the heat exchanger at a flow rate that does not fluctuate by more than 20 % of the average flow rate, in particular not by more than 10 % of the average flow rate. Even if these preferred conditions are not met, the described method can outperform prior art teachings.

[0019] Also, the temperature of the electrolysis medium downstream of the heat exchanger in general depends on the temperature of the electrolysis medium upstream of the heat exchanger. However, in case the electrolysis medium is circulated, the temperature of electrolysis medium upstream of the heat exchanger results from the temperature of the electrolysis medium downstream of the heat exchanger and from the heating caused by the electrolysis. This heating effect depends on the electrical energy supplied to the electrolysis stack. Hence, this heating can be predicted from the current density of the electrolysis stack and the cell voltage of the electrolysis stack. Thus, according to the described method, the flow rate F of the cooling medium is set to a value depending on a current value I_{cur} of the current density of the electrolysis stack and a current value V_{cur} of the cell voltage of the electrolysis stack. The current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack can be determined by measurement. Alternatively, these values can be extracted from a control unit, which supplies electrical energy to the electrolysis stack at these values.

[0020] Even if the electrolysis medium is not circulated and no heat exchanger is used, it is still reasonable to set the flow rate F of the cooling medium to a value depending on the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack. This is due to the fact that in general the temperature generated by the electrolysis depends on these parameters.

[0021] The current density is the electrical current applied to the electrolysis stack divided by the cell area of the electrolysis cells of the electrolysis sack. Herein, the letter I is used to indicate the current density. It is also common to use the letter I for the current and the letter *J* for the current density. Instead of the current density, the current applied to the electrolysis stack could be used as well. This is because the cell area is a constant. The cell voltage of the electrolysis stack is the voltage applied to each of the electrolysis cells of the electrolysis stack. For example, if the electrolysis cells of the electrolysis stack are electrically in series, the voltage applied to the electrolysis stack is the sum of the respective cell voltages applied to the electrolysis cells of the electrolysis stack. The cell voltage is preferably the same for all electrolysis cells. Hence, the cell voltage can be obtained by dividing the voltage applied to the electrolysis stack by the number of electrolysis cells the electrolysis stack has. This can even be done in case the electrolysis cells of the electrolysis stack are not identical to each other. In that case, an average cell voltage is obtained. It is generally preferred to use the average cell voltage as the cell voltage in the described method. Herein, the letter V is used for the cell voltage.

[0022] The described method is particularly fast. In particular, fluctuations in the supply of the electrical energy can be reacted to particularly quickly. To this end, the described method is particularly suitable to be used with renewable energies. It is thus preferred that electrical energy is supplied to the electrolysis stack from a renewable energy source. For example, the renewable energy source can be a solar power plant or a wind turbine. However, the described method is also applicable with any other energy source. The quick response according to the invention can be achieved in that the current density and the cell voltage of the electrolysis stack are used for the temperature control. A change in the supply of the electrical energy is expressed in that the current density and the cell voltage of the electrolysis stack change. To this end, the change in the supply of the electrical energy can be detected as such and the flow rate of the cooling medium can be adapted accordingly. If instead the temperature control was based on a temperature measurement, a change in the supply of the electrical energy could only be detected once the measured temperature changes. However, the temperature changes in such a case only with a delay. To this end, the temperature of the electrolysis process can be controlled with the described method particularly quickly. This results in a particularly accurate control.

[0023] According to a preferred embodiment of the method the flow rate F is set using a feedforward control process.

[0024] If the flow rate of the cooling medium was controlled based on a measurement of the temperature, this could be referred to as a feedback control process. This is because the result (i.e. the temperature) is observed and fed back to where a manipulation is possible (i.e. the cooling using a cooling medium at a certain flow rate). In contrast thereto, the described method constitutes a feedforward control process. Therein, the cause for a potential change (i.e. the supply of electrical energy that potentially could change the temperature) is observed and taken into account where a manipulation is possible (i.e. in the cooling using a cooling medium at a certain flow rate) even before the change actually occurs (i.e. the temperature actually changes).

[0025] According to a further preferred embodiment the method comprises:

a) providing a reference value F_{ref} of the flow rate of the cooling medium assigned to reference conditions, in which the current density of the electrolysis stack has a reference value I_{ref} and the cell voltage of the electrolysis stack has a reference value V_{ref},
b) determining the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack, and
c) setting the flow rate F of the cooling medium to a value depending on

- the reference value F_{ref} of the flow rate of the cooling medium, the reference value I_{ref} of the current density of the electrolysis stack and the reference value V_{ref} of the cell voltage of the electrolysis stack, and
- the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack.

[0026] In step a) a reference value F_{ref} of the flow rate of the cooling medium is provided. The reference conditions are defined, in particular, in that therein the current density of the electrolysis stack has a reference value I_{ref} and the cell voltage of the electrolysis stack has a reference value V_{ref}.

[0027] It is sufficient to perform step a) only once. Step a) can be considered a calibration step. The reference conditions can be chosen arbitrarily. For example, the reference conditions can be set to the current conditions at the time step a) is supposed to be carried out. That is, in order to perform step a), the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack can be determined, for example by measurement or by reading from a control unit, and the reference value I_{ref} of the current density of the electrolysis stack and the reference value V_{ref} of the cell voltage of the electrolysis stack can be defined to be equal to these values. The reference value F_{ref} of the flow rate of the cooling medium can be provided in that it is determined which flow rate is desired under the reference conditions. This can be done experimentally. Therein, the reference value F_{ref} can be set to a value that provides a satisfactory result.

[0028] Alternatively, the reference values F_{ref}, I_{ref} and V_{ref} can be determined theoretically. For example, the reference values I_{ref} and V_{ref} can be set to a arbitrary values and it can be calculated which flow rate of the cooling medium would be desired for these values.

[0029] As a further alternative, the reference values F_{ref}, I_{ref} and V_{ref} can be determined prior to the beginning of the described method.

[0030] Ideally, the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack deviate as little as possible from the respective reference values I_{ref} and V_{ref}. This will increase the accuracy of the described method. Hence, it is preferred that the reference value I_{ref} of the current density of the electrolysis stack and the reference value V_{ref} of the cell voltage of the electrolysis stack are defined to be respective average values of the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack, respectively, taken over a period of time. The period of time is preferably, at least an hour, in particular at least a day or even at least a week.

[0031] In step b) the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack are determined. This can be done by measurement or by reading from a control unit. Also, this can be done in that the respective values are calculated from other parameters that are measured or read from the control unit. It is sufficient that after step b) a value representing the current value I_{cur} of the current density of the electrolysis stack and a value representing the current value V_{cur} of the cell voltage of the electrolysis stack are known. For example, instead of the actual current value I_{cur} of the current density of the electrolysis stack and the actual current value V_{cur} of the cell voltage of the electrolysis, electrical signals could be used that represent the respective value.

[0032] In step c) the flow rate F of the cooling medium is set. This means that the actual flow rate of the cooling medium is affected, which results in a respective cooling effect on the electrolysis medium.

[0033] The flow rate F is set to a value that depends on the reference values F_{ref}, I_{ref} and V_{ref} as well as on the current values I_{cur} and V_{cur}. For example, the current values I_{cur} and V_{cur} can be compared with the respective reference value I_{ref} and V_{ref}. If there is no deviation, the flow rate F can be simply set to the reference value F_{ref}. If there is a deviation, the flow rate F can be set to a value that deviates from the reference value F_{ref} accordingly.

[0034] According to a further preferred embodiment of the method the value to which the flow rate F of the cooling medium is set in step c) further depends on

- a thermoneutral cell voltage V_{th} of the electrolysis stack.

[0035] The thermoneutral cell voltage V_{th} is the voltage drop across each of the electrolysis cells of the electrolysis stack that is sufficient not only to drive the electrolysis reaction, but to also provide heat so as to maintain a constant temperature. It was found that taking the thermoneutral cell voltage V_{th} into account can improve the accuracy of the described method.

[0036] According to a further preferred embodiment of the method the flow rate F of the cooling medium is set in step c) to

$$F = F_{ref} \frac{I_{cur} \cdot (V_{cur} - V_{th})}{I_{ref} \cdot \left(V_{ref} - V_{th}\right)}.$$

[0037] It was found that with the stated equation particularly good results can be obtained. However, acceptable results can also be obtained in alternative embodiments in which the flow rate is not set exactly according to this equation. For example, instead of the stated equation an approximation thereof could be used. Also, further parameters could be taken into account in determining the flow rate. To this end, the stated equation is only presented as a preferred embodiment.

[0038] According to a further preferred embodiment of the method, the value to which the flow rate F of the cooling medium is set further depends on a feedback correction ΔF_{FB}.

[0039] Setting the flow rate F of the cooling medium to a value depending on the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack has the above described advantage of being particularly quick. In order to increase reliability, the present embodiment further involves a feedback correction. This way, the advantage of a particular quick control can be combined with the accuracy of a feedback control.

[0040] The flow rate F of the cooling medium can be set to a value that is the sum of the feedback correction ΔF_{FB} and a contribution depending on the current value I_{cur} of the current density of the electrolysis stack and the current value V_{cur} of the cell voltage of the electrolysis stack. The latter can be referred to as a feedforward value F_{FF}. Hence, it is

$$F = F_{FF}(I_{cur}, V_{cur}) + \Delta F_{FB}\,.$$

Therein, $F_{FF}(I_{cur}, V_{cur})$ indicates that F_{FF} depends on I_{cur} and V_{cur}.

[0041] For example, in the case of the above described embodiment involving steps a) to c), the flow rate F of the cooling medium can be set in step c) to

$$F = F_{ref} \frac{I_{cur} \cdot (V_{cur} - V_{th})}{I_{ref} \cdot \left(V_{ref} - V_{th}\right)} + \Delta F_{FB}.$$

[0042] However, a feedback correction ΔF_{FB} can be taken into account in any other embodiment as well.

[0043] In an example, the feedback correction ΔF_{FB} is initially set to be equal to zero. The flow rate F is than set to $F_{FF}(I_{cur}, V_{cur})$. By measuring the temperature it can be checked whether or not the result obtained thereby is satisfying, for example by comparing the measured temperature with a temperature set point. In case the measured temperature equals the temperature set point, ΔF_{FB} remains zero. If the supply of electrical energy changes suddenly, for example in the case of a renewable energy source, this can be compensated for because $F_{FF}(I_{cur}, V_{cur})$ changes immediately. Ideally, this compensation is as accurate as that the temperature remains at the set point so that ΔF_{FB} remains zero. However, should any deviation between the measured temperature and the temperature set point be detected, this would indicated that the flow rate would be too high or too low, respectively. For example, particularly low external temperatures in winter could result in a flow rate that is too high. By setting ΔF_{FB} accordingly, such a deviation can be compensated for. In case the flow rate is too high, ΔF_{FB} is set to a negative value. If the supply of electrical energy is constant and the external conditions change, this can be compensated for by means of the feedback correction ΔF_{FB}. Since external conditions are unlikely to change quickly, it is therein acceptable that this control is slower.

[0044] It should be noted that the described feedback correction is only optional. This is due to the fact that the feedback correction is redundant.

[0045] According to a further preferred embodiment of the method the current value I_{cur} of the current density of the electrolysis stack is determined by measurement and/or the current value V_{cur} of the cell voltage of the electrolysis stack is determined by measurement.

[0046] As a further aspect of the invention an arrangement for performing an electrolysis is described that comprises:

- an electrolysis stack,
- a cooling installation that is configured for providing a cooling medium for the electrolysis at a flow rate F,
- a control unit that is electrically connected to the electrolysis stack and to the cooling installation and that is configured for controlling the arrangement so as to perform the electrolysis using a method configured as described.

[0047] The advantages and features of the method are transferrable to the arrangement, and vice versa. The method is preferably performed using the arrangement.

[0048] The cooling installation can be configured for providing the cooling medium for the electrolysis in that the cooling installation is configured for providing the cooling medium to a heat exchanger of a feed installation, wherein the heat exchanger is arranged upstream of the electrolysis stack. Alternatively, the cooling installation can be configured for providing the cooling medium to the electrolysis stack.

[0049] In the following the invention will be described with respect to the figures. The figures show a preferred embodiment, to which the invention is not limited. The figures and the dimensions shown therein are only schematic. The figures show:

Fig. 1:	an arrangement according to the invention,
Fig. 2a to 2c:	simulation data calculated for a conventional electrolysis arrangement,
Fig. 3a to 3c:	simulation data calculated for the arrangement of Fig. 1.

[0050] Fig. 1 shows an arrangement 2 with an electrolysis stack 1 configured for the electrolysis of water. The electrolysis stack 1 is connected to a feed installation 11, via which water can be fed to the electrolysis stack 1 as an electrolysis medium. In the shown example, the feed installation 11 is realized as a single feed that provides the water to both an anode and a cathode space of the electrolysis stack 1.

[0051] Within the electrolysis stack 1, an electrolysis can be performed with the water. The water remaining in the anode space can be guided together with the anode product, i.e. oxygen, from the electrolysis stack 1 to an anode separator 5. From the anode separator 5 the gaseous oxygen can be extracted via an oxygen outlet 8 and the liquid water can be fed back to the electrolysis stack 1. In order to compensate for losses of the water, new water can be introduced into the anode separator 5 via a water feed 7. That is, the feed installation 11 comprises the anode separator 5, the water feed 7 and the conduit from the electrolysis stack 1 to the anode separator 5 as well as the conduit from the anode separator 5 back to the electrolysis stack 1.

[0052] The water remaining in the cathode space can be guided together with the cathode product, i.e. hydrogen, from the electrolysis stack 1 to a cathode separator 6. From the cathode separator 6 the gaseous hydrogen can be extracted via a hydrogen outlet 9 and the liquid water can be extracted via a water outlet 12.

[0053] Within the conduit from the electrolysis stack 1 to the anode separator 5 a heat exchanger 10 is provided that is connected to a cooling installation 3. The cooling installation 3 is configured for providing a cooling medium for the electrolysis at a flow rate F. Within the heat exchanger 10 the water coming from the electrolysis stack 1 is cooled before it is fed back, via the anode separator 5, to the electrolysis stack 1. Since the water is circled back to the electrolysis stack 1, the water is cooled before being used in the electrolysis (again).

[0054] Further, the arrangement comprises a control unit that is electrically connected to the electrolysis stack 1 and to the cooling installation 3. The control unit is configured for controlling the arrangement 2 so as to perform an electrolysis using a method, in which the water used for the electrolysis is cooled by means of the cooling medium provided at a flow rate F, wherein the flow rate F of the cooling medium is set to a value depending on a current value I_{cur} of a current density of the electrolysis stack 1 and a current value V_{cur} of a cell voltage of the electrolysis stack 1.

[0055] In particular, the flow rate F of the cooling medium can be set to

$$F = F_{FF}(I_{cur}, V_{cur}) + \Delta F_{FB} = F_{ref}\,\frac{I_{cur}\cdot(V_{cur}-V_{th})}{I_{ref}\cdot\left(V_{ref}-V_{th}\right)} + \Delta F_{FB}.$$

[0056] This involves a feedforward term F_{FF} and a feedback correction ΔF_{FB}. The feedforward term is obtained in a feedforward control installation 4, which is part of the control unit. Therefore, the feedforward control installation 4 can receive the values I_{cur} and V_{cur} from the electrolysis stack 1 as indicated by two dotted lines. The further parameters of the feedforward term F_{FF} can be stored in a storage of the feedforward control installation 4. The feedback correction ΔF_{FB} can be obtained with a temperature controller TC, which is also part of the control unit. By adding the feedforward term F_{FF} and the feedback correction ΔF_{FB} using an adder (indicated as a circle with two plus signs), which is also part of the control unit, the flow rate F can be obtained. From the adder, this value can be communicated to a valve such that the actual flow rate is set accordingly.

[0057] Fig. 2a to 2c show data simulated for a conventional electrolysis arrangement (which is not shown in the figures). The conventional electrolysis arrangement has a single electrolysis stack with a heat exchanger and common separators that are placed horizontally. The temperature is controlled by means of a conventional PID control.

[0058] Fig. 2a illustrates the current density applied to the electrolysis stack of the conventional electrolysis arrangement over the time. It can be seen that a jump in the current density occurs shortly before 200 s. This is supposed to simulate a sudden change in the supply of electric energy to the electrolysis stack, for example in case a renewable energy source is used.

[0059] Fig. 2b and 2c show simulated data that illustrate how the conventional electrolysis arrangement reacts to the jump in the current density shown in Fig. 2a. To this end, in Fig. 2b and 2c the temperature is shown over the time. Fig. 2b refers to the start of operation and Fig. 2c to a later stage, where the electrolysis stack has degraded by 20 %. It can be seen that the jump in the current density results in a jump in the temperature by about 9 °C (Fig. 2b) and 13 °C (Fig. 2c), respectively.

[0060] Fig. 3a to 3c show data simulated for the arrangement 2 of Fig. 1. As can be seen from Fig. 3a, the same jump in the current density is simulated.

[0061] Fig. 3b and 3c show simulated data that illustrate how the arrangement 2 of Fig. 1 reacts to the jump in the current density. To this end, in Fig. 3b and 3c the temperature is shown over the time similar to Fig. 2b and 2c. Fig. 3b refers to the start of operation and Fig. 3c to a later stage, where the electrolysis stack has degraded by 20 %. It can be seen that the jump in the current density results in a jump in the temperature by about 3.5 °C (Fig. 3b) and 2 °C (Fig. 3c), respectively. To this end, the arrangement 2 of Fig. 1 addressed in Fig. 3a to 3c outperforms the conventional arrangement addressed in Fig. 2a to 2c.

[0062] Although Fig. 3a to 3c refer to a case with feedback correction ΔF_{FB} the same results could be obtained for various situations without feedback correction ΔF_{FB}, for example in case external conditions remain unchanged. This is particularly true because the effect of the feedback correction ΔF_{FB} is comparatively slow.

List of reference numerals

[0063]

1	electrolysis stack
2	arrangement
3	cooling installation
4	feedforward control installation
5	anode separator
6	cathode separator
7	water feed
8	oxygen outlet
9	hydrogen outlet
10	heat exchanger
11	feed installation
12	water outlet

Claims

1. Method for performing an electrolysis with an electrolysis stack (1), wherein an electrolysis medium is used for the electrolysis that is cooled by means of a cooling medium provided at a flow rate F, wherein the flow rate F of the cooling medium is set to a value depending on a current value I_{cur} of a current density of the electrolysis stack (1) and a current value V_{cur} of a cell voltage of the electrolysis stack (1).

2. Method according to claim 1, wherein the flow rate F is set using a feedforward control process.

3. Method according to any of the preceding claims, wherein the method comprises:

a) providing a reference value F_{ref} of the flow rate of the cooling medium assigned to reference conditions, in which the current density of the electrolysis stack (1) has a reference value I_{ref} and the cell voltage of the electrolysis stack (1) has a reference value V_{ref},
b) determining the current value I_{cur} of the current density of the electrolysis stack (1) and the current value V_{cur} of the cell voltage of the electrolysis stack (1), and
c) setting the flow rate F of the cooling medium to a value depending on

- the reference value F_{ref} of the flow rate of the cooling medium, the reference value I_{ref} of the current density

of the electrolysis stack (1) and the reference value V_{ref} of the cell voltage of the electrolysis stack (1), and
- the current value I_{cur} of the current density of the electrolysis stack (1) and the current value V_{cur} of the cell voltage of the electrolysis stack (1).

4. Method according to claim 3, wherein the value to which the flow rate F of the cooling medium is set in step c) further depends on

- a thermoneutral cell voltage V_{th} of the electrolysis stack (1).

5. Method according to claim 4, wherein the flow rate F of the cooling medium is set in step c) to

$$F = F_{ref}\frac{I_{cur} \cdot (V_{cur} - V_{th})}{I_{ref} \cdot \left(V_{ref} - V_{th}\right)}.$$

6. Method according to any of the preceding claims, wherein the value to which the flow rate F of the cooling medium is set further depends on a feedback correction ΔF_{FB}.

7. Method according to any of the preceding claims, wherein the current value I_{cur} of the current density of the electrolysis stack (1) is determined by measurement and/or the current value V_{cur} of the cell voltage of the electrolysis stack (1) is determined by measurement.

8. Arrangement (2) for performing an electrolysis, comprising:

- an electrolysis stack (1),
- a cooling installation (3) that is configured for providing a cooling medium for the electrolysis at a flow rate F,
- a control unit that is electrically connected to the electrolysis stack (1) and to the cooling installation (3) and that is configured for controlling the arrangement (2) so as to perform the electrolysis using a method according to any of the preceding claims.

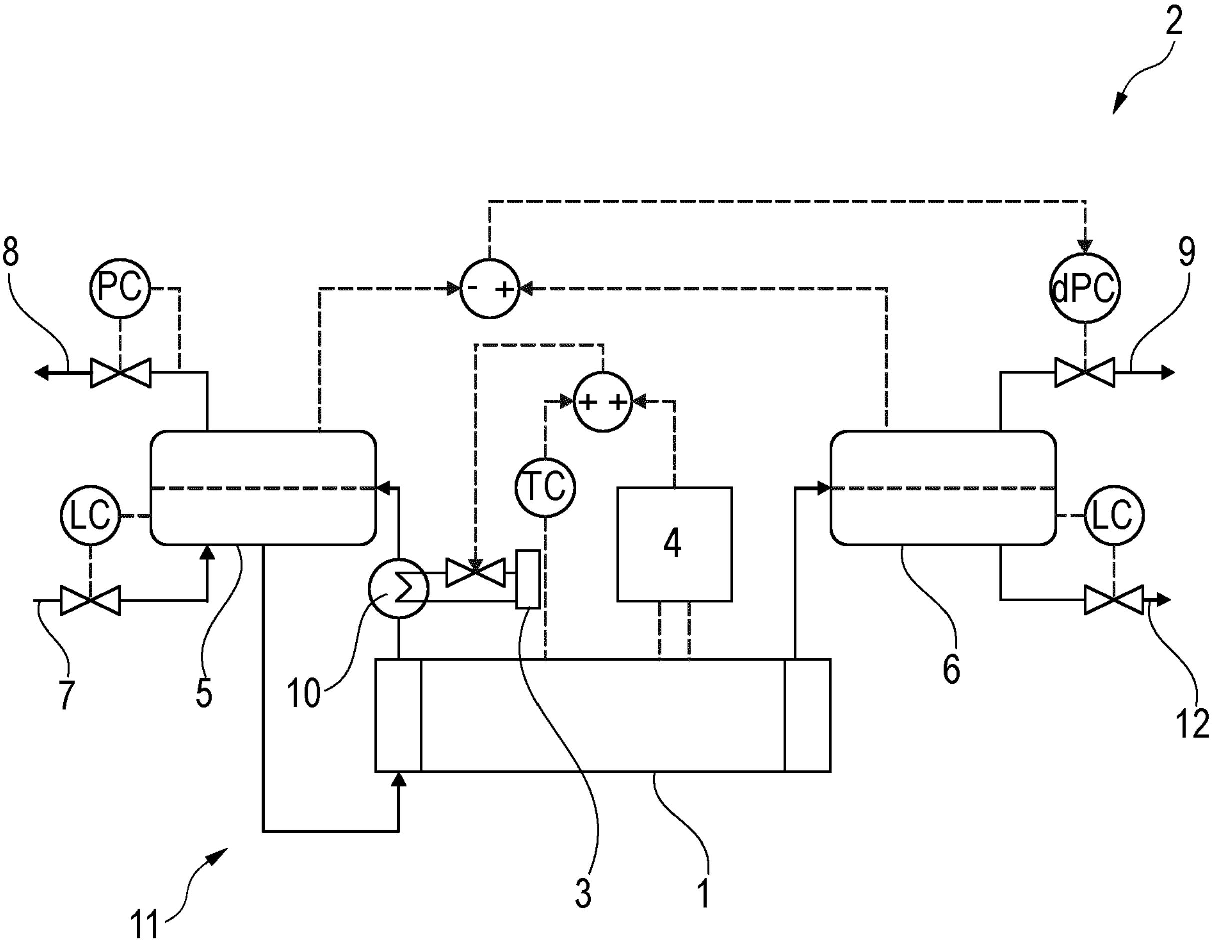

Fig. 1

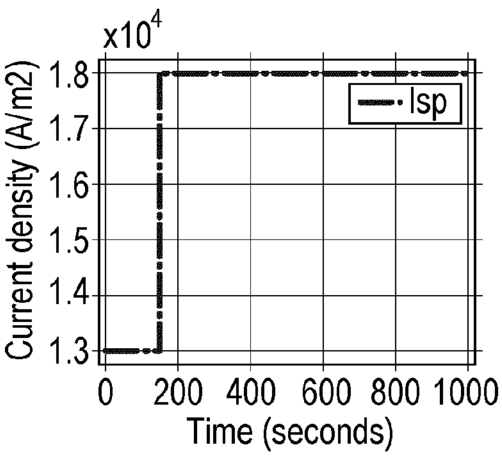

Fig. 2a

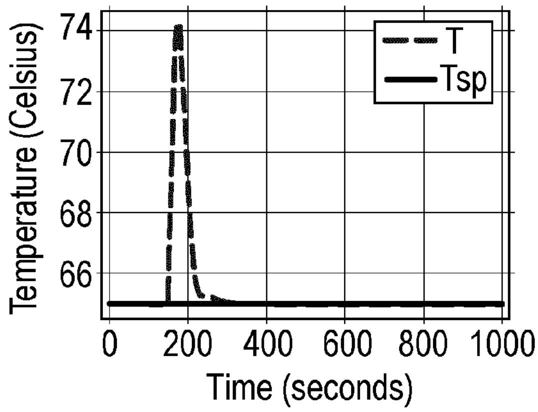

Fig. 2b

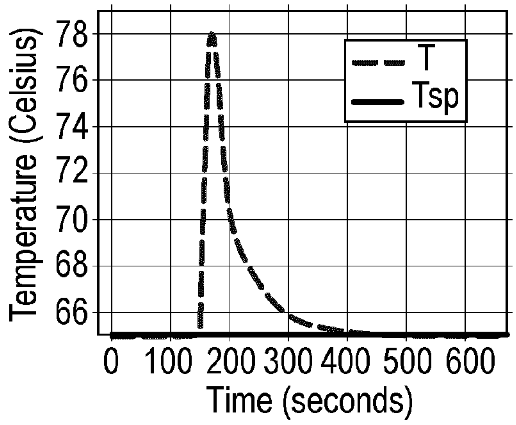

Fig. 2c

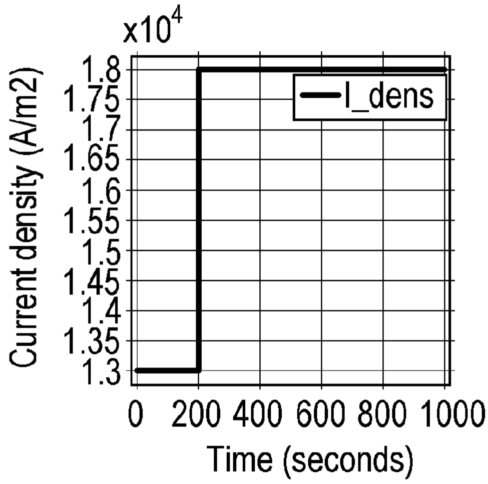

Fig. 3a

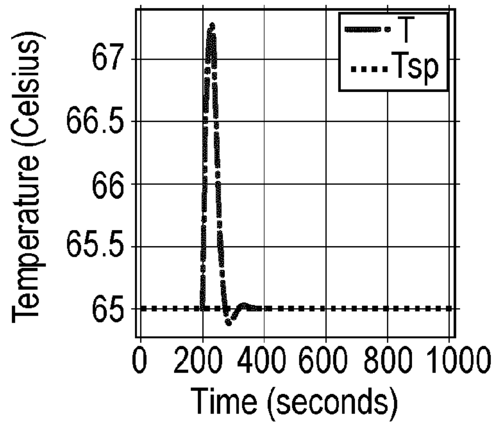

Fig. 3b

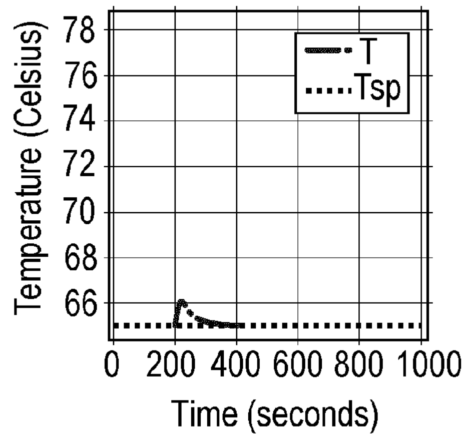

Fig. 3c

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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 3339

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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	25 October 2022	Teppo, Kirsi-Marja

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