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(54) AC to DC converter for electrolysis

(57) An AC/DC converting circuit for a turbine generator is provided. The converter comprises an active AC/DC converter having a controllable output voltage level having an input for receiving alternating current electrical power from a turbine generator and an output for providing direct current electrical power to an electrolysis system for electrolysis of water and a control unit. The control unit is arranged to receive data related to at least one of a state of the electrolysis system and the turbine generator, and adjust the output voltage based on the received data. By adjusting the output voltage of the AC/DC converter and with that, the input voltage to the electrolysis system, the relation between the output voltage of the AC/DC converter and the internal voltage over a membrane or other reaction medium within the electrolysis cell may be determined, so as to take impedance of the electrolysis cell into account.

P125977NL00

Title: AC to DC converter for electrolysis

TECHNICAL FIELD

The various aspects and implementations thereof relate to conversion of mechanical energy to electrical energy for electrolysis.

BACKGROUND

Whereas many advocate use of electrical energy to replace home use of natural gas and other fossil fuels, it has become apparent that at many locations, the current capacity of the electricity supply grid is all but sufficient to achieve this ideal of some. Yet, in may urban areas, also a supply grid for natural gas is available and this gas grid may be modified to be used for transportation of hydrogen. This allows for hydrogen to replace natural gas for supply of energy.

This insight raises the need for efficient generation of hydrogen. In view of carbon based energy sources becoming scarcer, preferably non-carbon related energy generation for hydrogen generation is used. Popular non-carbon energy sources are solar and wind. An issue with these energy sources is that the output power and with that, output power may vary, as output voltage and output current may vary.

SUMMARY

It is preferred to provide a direct current electrical power source arranged to provide a stable and appropriate voltage and current at the core of a hydrogen generator, for example over the membrane of a membrane water electrolysis system. To achieve this, the voltage at the (external) input of an electrolysis system - thus at the output of a DC power supply - may be kept constant, but this appears not to be sufficient for the preferred efficiency level of operation.

A first aspect provides an alternating current AC to direct current DC converting circuit for a turbine generator. The AC to DC converter comprises an active AC/DC converter having a controllable output voltage level having an input for receiving alternating current electrical power from a turbine generator and an output for providing direct current electrical power to an electrolysis system for electrolysis of water and a control unit. The control unit is arranged to receive data related to at least one of a state of the electrolysis system and the turbine generator, and adjust the output voltage based on the received data.

By adjusting the output voltage of the AC/DC converter and with that, the input voltage to the electrolysis system, the relation between the output voltage of the AC/DC converter and the internal voltage over a membrane or other reaction medium within the electrolysis cell may be determined.

Based on the determined internal voltage or obtained parameters related to the electrolysis module, an optimal voltage within the reactor may be determined as a reference voltage and based on that reference voltage and data related to at least one of a state of the electrolysis system and the turbine generator, an optimal output voltage of the AC/DC converter may be determined.

In various implementations, data may be obtained on gas pressure in the electrolysis system, like pressure of hydrogen, oxygen and/or steam may be obtained, impedance of the electrolysis may be obtained, internal temperature of a reactor in the electrolysis system may be obtained, torque on an axle of the turbine may be obtained, values of other parameters may be obtained or a combination thereof. Based on the values of these parameters and/or change of the values over time may be used to adjust the output voltage of the AC/DC converter.

In one implementation, the AC to DC converting circuit, further comprises an oscillator for generating an alternating current auxiliary signal of which the frequency is controlled by the control unit and a summation circuit for adding the alternating current signal to the output of the active AC DC converter. In this implementation, the control unit is arranged to determine the impedance of the electrolysis system and to control the oscillator frequency as a function of the determined impedance.

Implementations may be envisaged with a fixed frequency of the added alternating current signal or a frequency controlled by the control unit based on other parameters.

An imaginary part of the impedance of an electrolysis cell and a water electrolysis cell in particular may vary as a function of frequency. It is, for the electrolysis process and the circuitry around it, preferred to keep the amount of reactive power in the circuitry as small as possible - and hence to keep the imaginary part of the impedance as small as possible. Alternatively or additionally, the control unit may determine a reactive power demanded by or fed to the electrolysis module and control the frequency based on the determined reactive power in any way, including implementations discussed below.

In another implementation of the AC to DC converting circuit the control unit is arranged to determine whether the impedance of the electrolysis system has an inductive character or a capacitive character, control the oscillator to increase the frequency of the alternating current auxiliary signal if the impedance has a capacitive character; and control the oscillator to decrease the frequency of the alternating current auxiliary signal if the impedance has an inductive character. This embodiment allows for appropriate control of reactive power demanded and consumed by the electrolysis module.

In particular implementation, the active AC DC converter comprises an AC to DC converter subsystem for converting the alternating current electrical power from the turbine generator to internal direct current electrical power, a DC to DC converter having a controllable output voltage level controllable by the control unit and a DC to AC converter arranged to convert the internal direct current electrical power to output alternating current power at a level, phase and frequency matched to an external grid for providing the output alternating current power to the external grid.

A second aspect provides a power conversion system. The system comprises: a turbine generator and the alternating current AC to direct current DC converting circuit according to the first aspect of which the input is electrically coupled to an electrical output of the turbine generator.

An implementation of the second aspect further comprises an electrolysis system for electrolysis of water electrically coupled to the output of the active AC DC converter.

In another implementation of the power supply system, the electrolysis system comprises at least one electrolysis cell and at least one of a temperature sensor for sensing internal temperature of the electrolysis cell and a pressure sensor for sensing pressure of at least one gas in the electrolysis cell. In this implementation, the at least one of the temperature sensor and the pressure sensor is coupled to the control unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The various aspects and implementations thereof will now be discussed in further detail in conjunction with drawings. In the drawings:

Figure 1: shows a power conversion system;

Figure 2: shows an example of an active AC/DC converter;

Figure 3: shows a schematic representation of phase/frequency of a water electrolysis cell;

Figure 4: shows a flowchart; and

Figure 5: shows a further power conversion system.

DETAILED DESCRIPTION

Figure 1 discloses an energy conversion system 100. The energy conversion system 100 comprises a turbine generator 120 connected to a rotor 124 for converting mechanical energy of the rotor 124 rotating to electrical energy. The rotor 124 may be arranged to be rotated by virtue of wind - streaming air -, streaming water or another flowing medium. In another embodiment, the turbine generator may be driven by a combustion engine or another driving system. The turbine generator 120 may be further implemented as any available converter, like an alternator, a dynamo, other, or a combination thereof.

The energy conversion system 100 further comprises an alternating current to direct current converter 130 - also referred to as an AC/DC converter 130. The output of the AC/DC converter 130 is coupled to an electrolysis module 160 arranged for electrolysis of water - dihydrogen oxide -, resulting in hydrogen and oxygen. The energy conversion system 100 comprises one or more electrolysis modules that are provided in parallel and/or in series to one another relative to the AC/DC converter 130.

The AC/DC converter 130 is an active AC/DC converter, which means that the output voltage of the AC/DC converter 130 may be adjusted between zero and a maximum voltage that is, among others, set by the voltage provided by the turbine generator 120.

Figure 2 shows an example of the active AC/DC converter 130. The AC/DC converter 130 comprises a full-bridge rectifier 230 provided by six IGBTs 232 as active electronic switches. Instead of IGBTs, also other electronic switches like MOSFETs, other field effect transistors or other types of fully controllable - on and off - semiconductor switches may be used. Between an alternating current source - connected at the left of the scheme shown by Figure 2 - and the rectifier 230, a first pass filter 212 is provided by means of one inductance 222 per phase.

The first pass filter 212 is followed by a second pass filter 214 provided by three capacitances 224 in star configuration between the phases and optionally grounded at the centre of the star and a third filter 216 provided by three inductors. Alternatively, the three capacitances 224 are provided in delta configuration. The second pass filter 214 is followed by a third pass filter 216 provided by three further inductances 226; one per phase. The output of the third pass filter is connected to the rectifier bridge 230. At the output of the AC/DC converter 130, a low-pass filter 240 is provided by means of a further capacitance 242. Whereas the AC/DC converter 130 of Figure 2 is depicted for handling three phases, other types of AC/DC converters may be envisaged with one, two or more than three phases.

The energy conversion system 100 further comprises a control unit 110 for controlling operation of the energy conversion system 100 and the various elements thereof. The control unit 110 is coupled to a control memory 112. The control memory 112 is arranged to store computer executable code for programming the control unit 110 to enable the control unit 110 to control the power conversion system 100 or at least part thereof. The control memory 112 is further arranged to store reference data that allows the control unit 110 to interpret sensor data and use the interpreted sensor data or other sensor data to control the power conversion system and particular parts thereof.

The control unit 110 is connected to an IGBT driver 150 for controlling switching of the IGBTs 232 or other electronic switches of the AC/DC converter 130.

The control unit 110 is further connected to a turbine sensor 122 provided in the turbine generator 120 for receiving data on torque and rotational speed of the axis of the turbine generator 120. The torque may be measured as the actual torque on the rotor 124, but preferably, the torque on the rotor 124 is determined based on current and voltage received by or from the AC/DC converter 130 and data on the turbine generator 120 that may be stored in the control memory 112.

The control unit 110 is further connected to a pressure sensor 164 for monitoring pressure in the electrolysis module 160 and hydrogen pressure in particular, a temperature sensor 166 for monitoring temperature in the electrolysis module 160 and an impedance sensor 168 for measuring impedance of the electrolysis module 160. Additionally, the control unit 110 may receive data on a speed of wind acting on the rotor 124.

The electrolysis module 160 comprises a cathode 180 connected to a negative side of the AC/DC converter 130 and an anode 170 connected to a positive side of the AC/DC converter 130. Water is provided to the anode 170 through an anode inlet 172 and hydrogen is provided by the cathode 180 as a result of operation via a cathode outlet 184. Between the anode 170 and the cathode 180, a membrane 162 is provided. At the anode side of the membrane 162, an anode reaction space 176 is provided and at a cathode side of the membrane 162, a cathode reaction space 186 is provided.

In the implementation shown by Figure 1, water is provided to the anode 170, as is common with membrane electrolysers. In another implementation, solid oxide electrolysers may be used, in which case water is provided to the cathode 180.

In operation, the rotor 124 rotates by virtue of wind, water or another external force and drives the turbine generator 120 which, in turn provided electrical energy by means of an alternating current. The alternating current is transformed to direct current electrical power by means of the AC/DC converter 130 and provided to the electrolysis module 160 for generating hydrogen.

The power conversion system 100 further comprises an alternating current signal source 140 connected to the output of the AC/DC converter by a summation circuit comprising a first summation element 146 and a second summation element 144. In another embodiment, only one summation element is provided. The alternating current signal source 140 is connected to the control unit 110 and the control unit 110 is arranged to control frequency and amplitude of an alternating current power signal to be added to the output of the AC/DC converter 130.

The alternating current signal source 140 comprises a reactive power monitor 142 for measuring reactive power provided by the alternating current signal source 140 or for measuring a phase difference between current and voltage of the alternating current power signal provided by the alternating current signal source 140.

At lower frequencies, the electrolysis module 160 has an capacitive character and at higher frequencies, the electrolysis module 160 has a inductive character. In both cases, the electrolysis module 160 consumes reactive power. This consumption of reactive power is undesired, as it may result in high currents that require robuster design of the power conversion system 100.

Figure 3 schematically shows a phase-frequency characteristic of the electrolysis module 160: at frequencies below f_0, the phase shift is negative and at frequencies below f_0, the phase shift is positive. The reactive power monitor 142 is arranged to monitor, over the operating frequencies of the alternating current signal source 140, what operating frequency matches f_0 best, i.e. at what frequency the phase shift is lowest. With this information, the control unit 110 is arranged to operate the alternating current signal source 140 at a frequency at which the phase shift is as small as possible. Otherwise state, the alternating current signal source 140 preferably operates at a frequency at which the imaginary part of the impedance of the electrolysis module 160 is as low as possible. Alternatively or additionally, this control functionality is provided within the alternating current signal source 140.

The frequency of f_0 preferably lies between $5\ 10^2$ Hz and $2\ 10^3$ Hz, more preferably between $7.5 \cdot 10^2$ Hz and $1.5 \cdot 10^3$ Hz and even more preferably between $9 \cdot 10^2$ Hz and $1.1 \cdot 10^3$ Hz. In other embodiments, the frequency of f_0 may lie lower, between $5 \cdot 10^1$ Hz and $1.5 \cdot 10^2$ Hz, preferably between $8 \cdot 10^1$ Hz and $1.2 \cdot 10^2$ Hz and more preferably between $9 \cdot 10^1$ Hz and $1.1 \cdot 10^2$ Hz. In further embodiments, f_0 lies in same ranges around $2 \cdot 10^2$ Hz, $3 \cdot 10^2$ Hz, $4 \cdot 10^2$ Hz, $4 \cdot 10^2$ Hz, $5 \cdot 10^2$ Hz, $6 \cdot 10^2$ Hz, $7 \cdot 10^2$ Hz, $8 \cdot 10^2$ Hz, $9 \cdot 10^2$ Hz, depending on the design of the electrolyser cells of the electrolysis module 160, The amplitude of the signal provided by the alternating current signal source 140 is preferably a tenth of the value of the signal provided by the AC/DC converter 130 in terms of voltage.

The operation of the power conversion system 100 will be discussed below in further detail in conjunction with a flowchart 400 shown by Figure 4. The various parts of the flowchart 400 are briefly summarised below:

402	initialise system
404	obtain impedance of the electrolysis module;
406	adjust output voltage
408	adjust frequency
410	obtain temperature of the electrolysis module
412	adjust output voltage;
414	obtain hydrogen pressure in the electrolysis module;
416	adjust output voltage;
418	obtain torque of the turbine generator axis;
420	adjust output voltage;
422	switch electrolyser connections;
424	end procedure (return to start)

The procedure starts in a terminator 402 in which various parts of the power conversation system 100 are initialised. In step 404, the impedance of the electrolysis module 160 is obtained. This impedance may be obtained by means of the reactive power monitor 142 or the impedance sensor 168. Alternatively or additionally, the impedance or at least the resistance - real part of the impedance - of the electrolysis module 160 is obtained using data on the lifetime of the electrolysis module 160.

The lifetime data may be monitored by means of the control unit 110, using for example an internal clock. Reference data like a table stored in the control memory 112 on a relation between age and internal resistance of the electrolysis module 160 may be looked up to determine the actual internal resistance.

The internal resistance of the electrolysis module 160 increase with lifetime, which means that in order to keep the voltage across the membrane 162 at substantially the same level that is required for the electrolysis, the external voltage is to be increased. This external voltage is determined by the output voltage of the AC/DC converter 130. In step 406, the output voltage of the AC/DC converter 130 is adjust to compensate for any increase of internal resistance of the electrolysis module 160.

In step 408, the frequency of the alternating current signal source 140 is adjusted as discussed above, to arrive at an imaginary part of the operating impedance of the electrolysis module 160 that is as small as possible.

In step 410, temperature of the electrolysis module 160 is obtained, preferably by means of the temperature sensor 166. Based on the obtain data, optionally using reference data stored in the control memory 112, the AC/DC converter 130 is controlled to adjust the output voltage accordingly in step 412. If the temperature has increased compared to a previous period, the output is increased and if the temperature has decreased compared to a previous period, the output voltage is decreased.

In step 414, pressure of hydrogen in the electrolysis module 160 is obtained. This pressure may obtained at the output 174, in the anode reaction space 176 near the membrane, at another location of a combination thereof. Additionally or alternatively, pressures of other gases - oxygen, steam - in the electrolysis module 160 may obtained. Based on the obtain data, optionally using reference data stored in the control memory 112, the AC/DC converter 130 is controlled to adjust the output voltage accordingly in step 416. If the pressure has increased compared to a previous period, the output voltage is increased and if the pressure has decreased compared to a previous period, the output voltage is decreased.

In step 414, pressure of oxygen in the electrolysis module 160 is obtained. This pressure may obtained at the output 174, in the anode reaction space 176 near the membrane, at another location of a combination thereof. Additionally or alternatively, pressures of other gases in the electrolysis module 160 may obtained. Based on the obtain data, optionally using reference data stored in the control memory 112, the AC/DC converter 130 is controlled to adjust the output voltage accordingly in step 416. If the pressure has increased compared to a previous period, the output is increased and if the pressure has decreased compared to a previous period, the output voltage is decreased.

In step 418, torque on the turbine generator axis is obtained. Based on the obtained data, optionally using reference data stored in the control memory 112, the AC/DC converter 130 is controlled to adjust the output voltage accordingly in step 420. The output voltage is controlled such that the voltage over the membrane 162 is kept or set at a preferred level. As an increased torque may lead to increased current through the system, there will be an increased voltage of an internal resistance of the electrolysis module, resulting in a lower voltage over the membrane 162. To keep the voltage over the membrane 162 at the appropriate level, the output voltage of the AC/DC converter 130 may be increased in step 422 if the torque on the turbine generator axis increases.

The torque of the rotor 124 of the turbine generator 120 depends on the current and voltage taken up and provided by the AC/DC converter

130, thus the total power in the end consumed by the electrolysis module 160. For the turbine generator 120, based on parameters of the turbine itself, as well as the rotor 124 and, optionally, of other components of the system 100, also a maximum rotational speed of the rotor 124 and/or a preferred range of rotational speed may be set. Based on a given speed of the wind and system parameters, this maximum speed and/or speed range may be translated to a desired torque or desired torque range, for a particular value of the speed of the wind.

Based on this determined torque or torque range, in turn, a power may be determined to be taken from the AC/DC converter; power is the product of torque and angular speed.

The electrolysis module 160 may comprise one or more electrolysis cells, provided in series with or parallel to the AC/DC converter 130 or a combination thereof. Such configuration has influence of the voltage to be provided to the electrolysis module 160. Furthermore, electrolysis cells may be changed and different electrolysis cells may have different internal impedances or may require different voltages across their membranes. To address this, the control memory 112 may have stored in it a reference voltage that is to be applied across the membrane 162 and using data obtained by the various sensors, a desired output voltage of the AC/DC converter 130 is determined by the control unit 110.

In order to match power that needs to be taken from the turbine generator for a desired torque thereof and to be consumed by the electrolysis module 160, the AC/DC converter 130 and the switching of the various electrolysis cells in the electrolysis module 160 may be switched such that each electrolysis cell has the appropriate voltage applied across the membrane 162 of each cell. The various electrolysis cells may be switched in step 422 from serial to parallel configuration and some cells may be switch on or off to ensure an appropriate voltage across each of the membranes of the electrolysis cells and the appropriate power to be taken up by the electrolysis module 160.

In terminator 424, the adjustment procedure ends. Preferably, the procedure as depicted by the flowchart 400 is carried out again, optionally after passing through a waiting loop.

Figure 5 depicts a further power conversion system 500. The further power conversion system 500 comprises the same elements as the power conversion system 100. These elements are referenced by means of the same reference numerals, arranged to provide the same functionality as discussed above and not discussed in further detail again in conjunction with Figure 5.

In the embodiment according to Figure 5, the AC/DC converter 130 may be implemented using a passive rectifying module. To the output of the AC/DC converter 130, a direct current to direct current converter 196 - DC/DC converter - may be connected. The DC/DC converter 196 may be controlled, by the control unit 110, to provide an output voltage at a particular level, suitable for providing an appropriate voltage to the electrolysis system 160.

To the output of the AC/DC converter 130, also a direct current to alternating current converter 192 - DC/AC converter - is provided. The DC/AC converter 196 may be controlled by the control unit 110 or by another control unit (not shown). The output of the DC/AC converter 196 may be connected to a large area or local power grid 190, optionally via a bandpass filter 194 or other filter to remove any low or high frequency components - for example other than 50 Hz or 400 Hz (for aviation purposes) - from the signal generated by the DC/AC converter 192.

The further power conversion system 500 allows power generated by the turbine generator 120 to be distributed to the electrolysis module 160 and/or the power grid 190 and determine a ratio between both, depending on power supplied by the turbine generator 120 and the demand by the power grid 190. If the demand by the power grid 190 is low, most power generated by the turbine generator 120 may be provided to the electrolysis system 160. In yet further embodiments, another power supply module, for example fuel cell or a fuel cell system comprising multiple fuel cells, a solar power plant, another turbine generator, other, or a combination thereof, may be added to the further power conversion system 500 to provide additional electrical power to the further power conversion system 500 to be distributed.

Conclusies

1. Wisselstroom AC naar gelijkstroom DC conversiecircuit voor een turbine generator, omvattende:

een actieve AC/DC omzetter met een bestuurbaar uitgangsspanningsniveau met een ingang voor ontvangen van wisselstroom elektrisch vermogen van een turbine generator en een uitgang voor leveren van gelijkstroom elektrisch vermogen aan een elektrolysesysteem voor elektrolyse van water;

een besturingseenheid ingericht om:

- gegevens te ontvangen gerelateerd aan ten minste een van een staat van het elektrolysesysteem en de turbine generator; en
- de uitgangsspanning aan te passen op basis van de ontvangen gegevens.

2. AC naar DC conversiecircuit volgens conclusie 1, verder omvattende:

- een oscillator voor genereren van een wisselstroomhulpsignaal waarvan de frequentie wordt bestuur door de besturingseenheid; en
- een sommatiecircuit om het wisselspanningssignaal op te tellen bij de uitgang van de actieve AC/DC omzetter;

waarbij de besturingseenheid is ingericht om de impedantie van het elektrolysesysteem te bepalen en de oscillatorfrequentie te besturen als een functie van de bepaalde impedantie.

3. AC naar DC conversiecircuit volgens conclusie 2, waarbij de besturingseenheid is ingericht om:

- te bepalen of de impedantie van het elektrolysesysteem een inductief of een capacitief karakter heeft;
- de oscillator te besturen om de frequentie van het wisselstroomhulpsignaal te verlagen als de impedantie een inductief karakter heeft; en

- de oscillator te besturen om de frequentie van het wisselstroomhulpsignaal te verhogen als de impedantie een capacitief karakter heeft.

4. AC naar DC conversiecircuit volgens een van de voorgaande conclusies, waarbij de besturingseenheid is ingericht om gegevens met betrekking tot gasdruk in het elektrolysesysteem te ontvangen en om de uitgangsspanning te verhogen als de gasdruk toeneemt in verloop van tijd en om de uitgangsspanning te verlagen als de gasdruk afneemt in verloop van tijd.

5. AC naar DC conversiecircuit volgens een van de voorgaande conclusies, waarbij de besturingseenheid is ingericht om gegeven te verkrijgen met betrekking tot interne impedantie van het elektrolysesysteem en de besturingseenheid is ingericht om de uitgangsspanning te verhogen als de interne impedantie van het elektrolysesysteem toeneemt.

6, AC naar DC conversiecircuit volgens conclusie 3, waarbij de besturingseenheid is ingericht om:

- operationele leeftijd van het elektrolysesysteem te verkrijgen;
- gegevens te verkrijgen met betrekking tot een relatie tussen interne impedantie van het elektrolyse systeem; en
- de interne impedantie van het elektrolysesysteem te bepalen op basis van de ontvangen gegevens.

7. AC naar DC conversiecircuit volgens een van de voorgaande conclusies, waarbij de besturingseenheid is ingericht om gegevens te verkrijgen met betrekking tot interne temperatuur van het elektrolysesysteem en de besturingseenheid is ingericht om de uitgangsspanning te verhogen als de interne temperatuur van het elektrolysesysteem toeneemt.

8. AC naar DC conversiecircuit volgens een van de voorgaande conclusies, waarbij de besturingseenheid is ingericht om gegevens te verkrijgen met betrekking tot het koppel op een aandrijfas van de turbine generator en de besturingseenheid is ingericht om de uitgangsspanning te verhogen als het koppel toeneemt.

9. AC naar DC conversiecircuit volgens een van de voorgaande conclusies, waarbij de besturingseenheid is ingericht om een referentiespanning te verkrijgen en de besturingseenheid is ingericht om de uitgangsspanning te besturen op basis van de referentiespanning.

10. AC naar DC conversiecircuit volgens een van de voorgaande conclusies, waarbij de actieve AC naar DC omzetter omvat:

- een AC naar DC omzetter subsysteem voor omzetten van het wisselstroom elektrische vermogen van de turbine generator om te zetten naar een intern gelijkstroom elektrisch vermogen;
- een DC naar DC omzetter met een bestuurbaar uitgangsspanningsniveau bestuurbaar door de besturingseenheid; en
- een DC naar AC omzetter ingericht om het interne gelijkstroom elektrisch vermogen om te zetten naar een uitgangswisselstroomvermogen op een niveau, fase en frequentie passend bij een extern netwerk voor leveren van uitgangswisselstroomvermogen aan het externe netwerk.

11. Vermogensvoorzieningssysteem omvattende:

- een turbine generator; en
- een wisselstroom AC naar gelijkstroom conversiecircuit volgens een van de voorgaande conclusies waarvan de ingang elektrisch gekoppeld is aan een elektrische uitgang van de turbine generator.

12. Vermogensvoorzieningssysteem volgens conclusie 11, verder omvattende een elektrolysesysteem voor elektrolyse van water elektrische gekoppeld aan de uitgang van de actieve AC DC omzetter.

13. Vermogensvoorzieningssysteem volgens conclusie 12, waarbij het elektrolysesysteem ten minste een elektrolysecel omvat en ten minste een van:

- Een temperatuursensor voor voelen van een interne temperatuur van de elektrolysecel; en
- Een druksensor voor voelen van een druk van ten minste een gas in de elektrolysecel;

Waarbij de ten minste een van de temperatuursensor en de druksensor is gekoppeld aan de besturingseenheid.

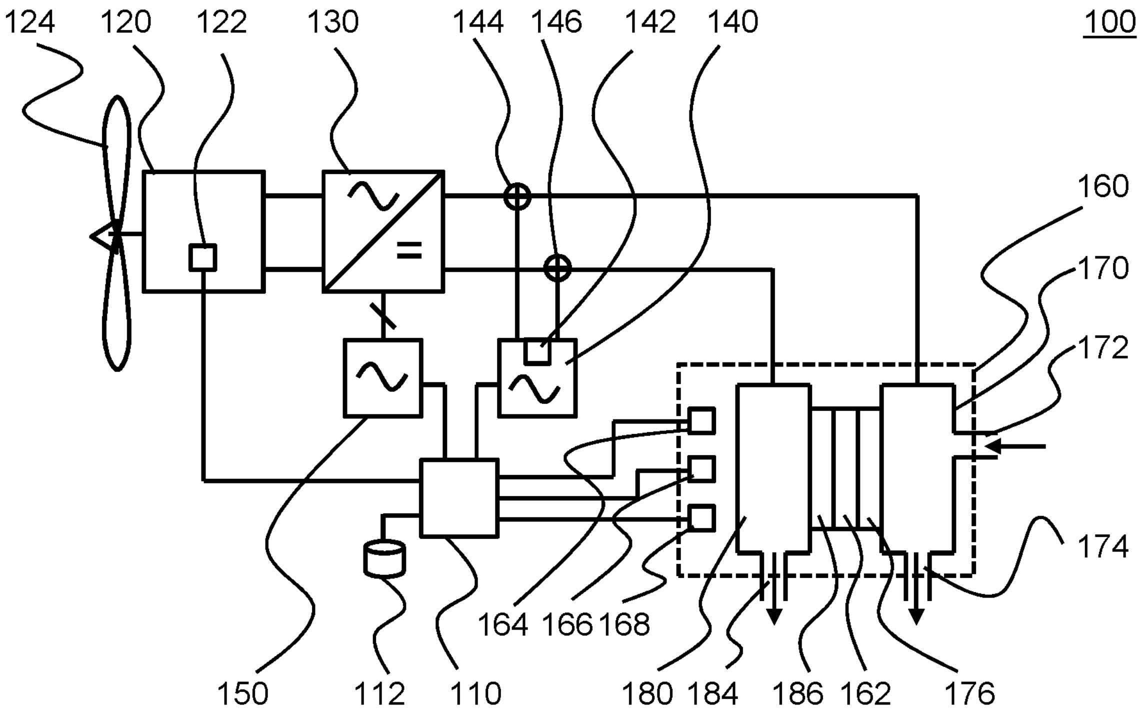

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Fig. 1

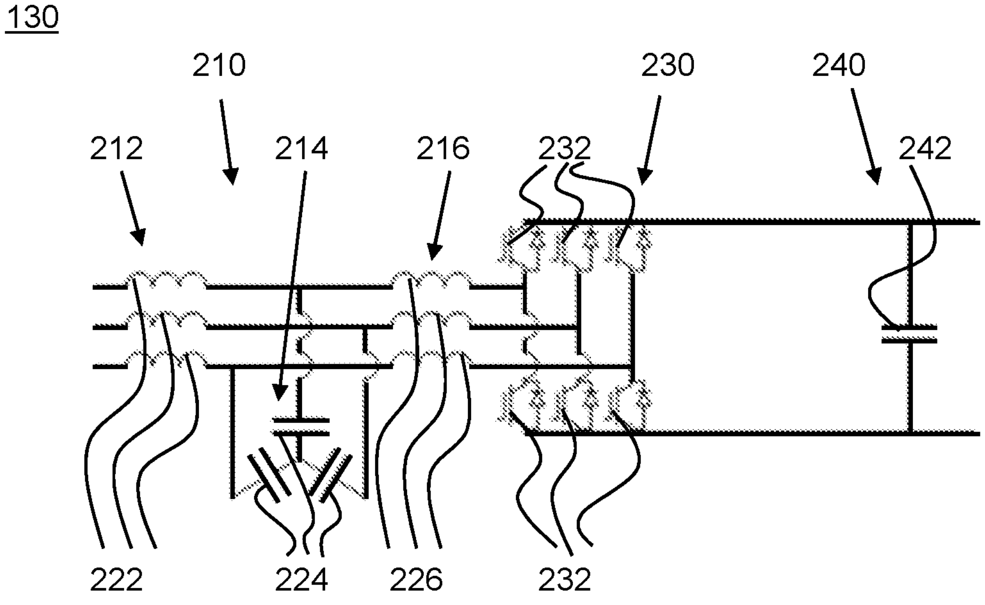

Fig. 2

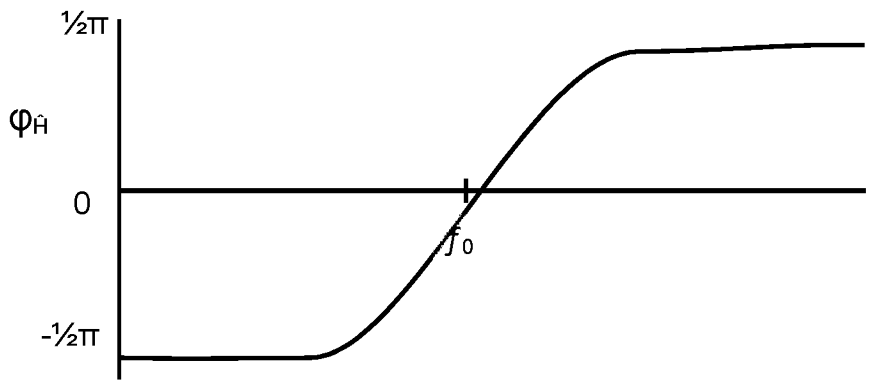

Fig. 3

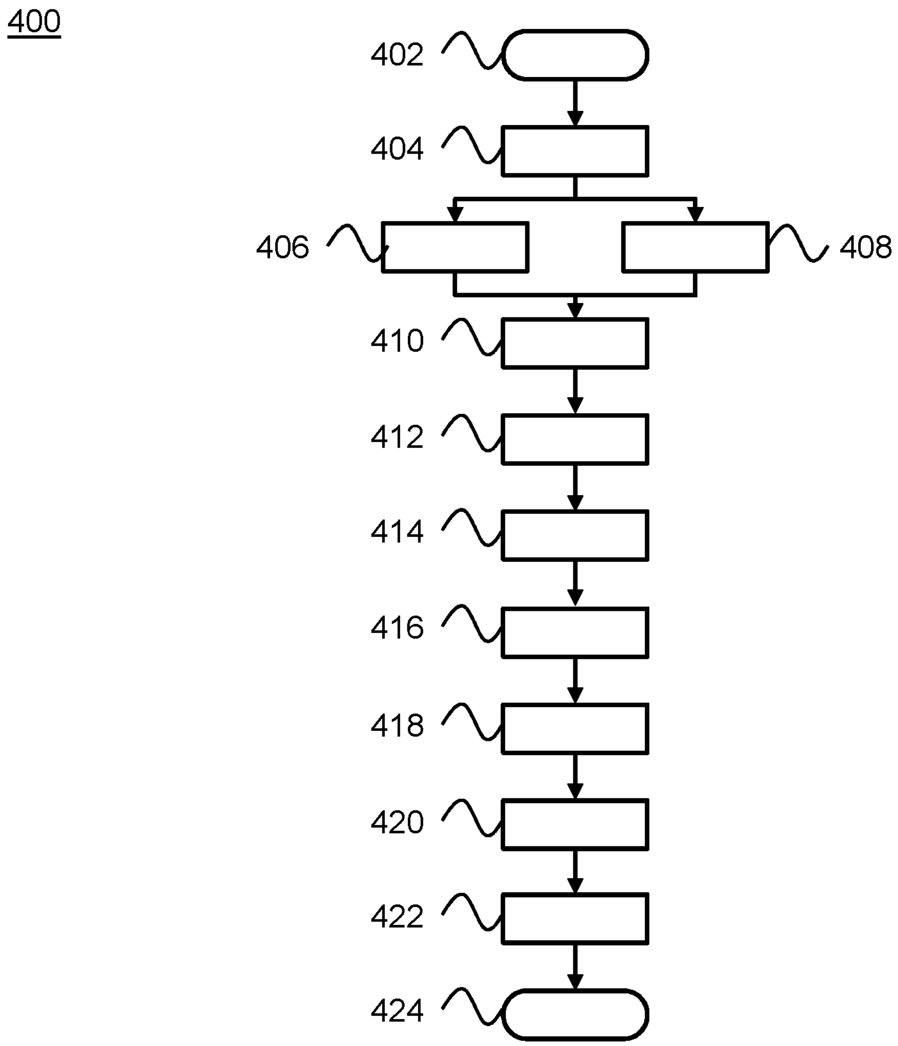

Fig. 4

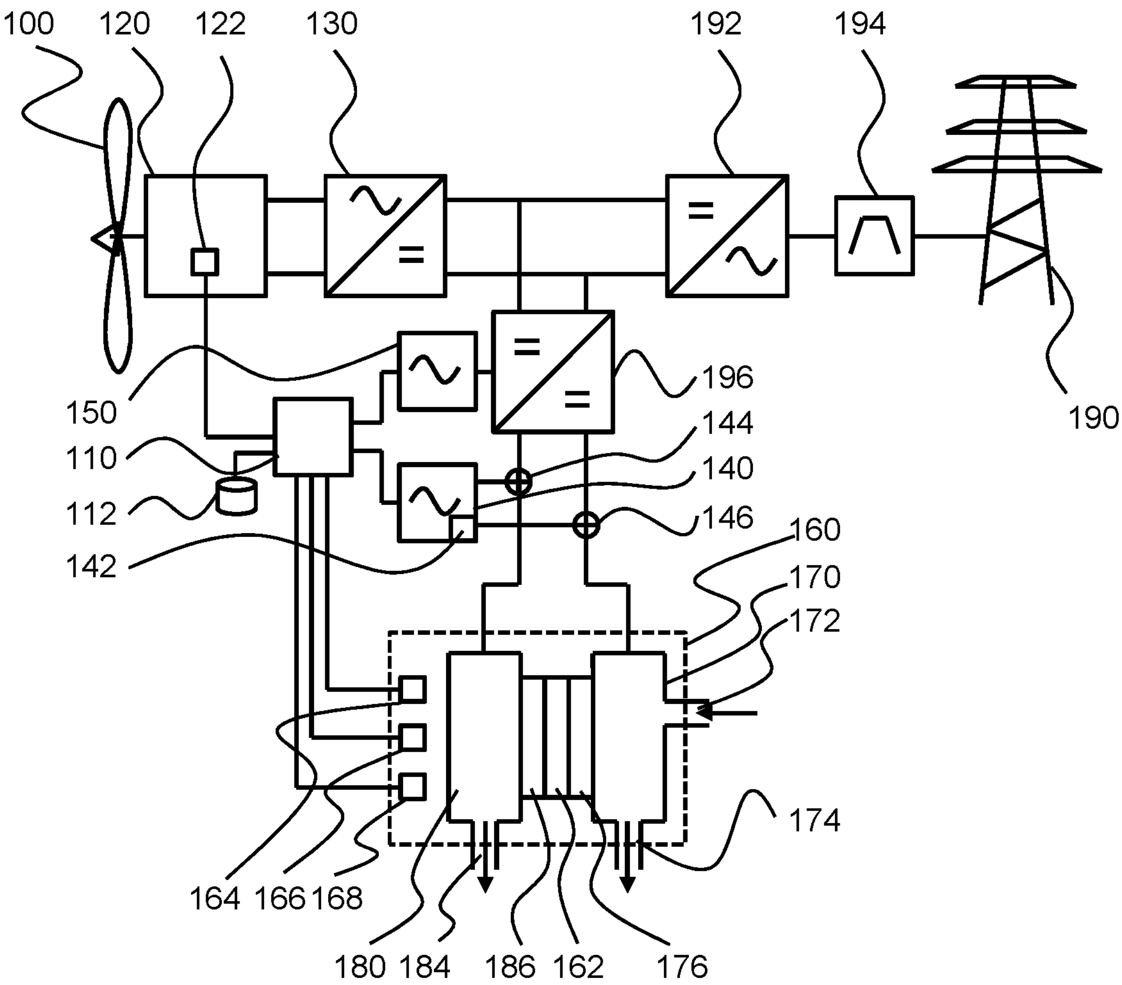
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Fig. 5

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	**KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE** **P125977NL00**
Nederlands aanvraag nr. **2024917**	Indieningsdatum **14-02-2020**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **HYGRO Technology BV**	
Datum van het verzoek voor een onderzoek van internationaal type **04-04-2020**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN75883**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

Zie onderzoeksrapport

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie	
Classificatiesysteem	Classificatiesymbolen
IPC	**Zie onderzoeksrapport**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.	☐	**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	☐	**GEBREK AAN EENHEID VAN UITVINDING**	(opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2024917

A. CLASSIFICATIE VAN HET ONDERWERP
INV. C25B1/04 H02K7/18
ADD. H02M1/14 H02M7/219

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte miminum documentatie (classificatie gevolgd door classificatiesymbolen)
H02M C25B H02K

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	DE BATTISTA H ET AL: "Power conditioning for a wind-hydrogen energy system", JOURNAL OF POWER SOURCES, ELSEVIER SA, CH, deel 155, nr. 2, 21 april 2006 (2006-04-21), bladzijden 478-486, XP027937651, ISSN: 0378-7753 [gevonden op 2006-04-21] * samenvatting * * * Delen 1 and 2 op pagina's 478-481 * ----- -/--	1-13

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[ ] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

8 oktober 2020

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie
European Patent Office, P.B. 5818 Patentlaan 2
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De bevoegde ambtenaar

Standaert, Frans

C.(Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	BINTZ STEFFEN ET AL: "Parallel-Serial-Rectifier for Power-to-Hydrogen Applications", 2019 21ST EUROPEAN CONFERENCE ON POWER ELECTRONICS AND APPLICATIONS (EPE '19 ECCE EUROPE), EPE ASSOCIATION, 3 september 2019 (2019-09-03), XP033665765, DOI: 10.23919/EPE.2019.8915526 [gevonden op 2019-11-26] * het gehele document * -----	1-13
A	BINTZ STEFFEN ET AL: "Load Emulation for Electrolysis Rectifiers", 2019 IEEE 13TH INTERNATIONAL CONFERENCE ON POWER ELECTRONICS AND DRIVE SYSTEMS (PEDS), IEEE, 9 juli 2019 (2019-07-09), bladzijden 1-7, XP033719305, DOI: 10.1109/PEDS44367.2019.8998887 [gevonden op 2020-02-13] * Deel I op pagina 1 * * Deel 2 op pagina 3 * -----	1-13

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WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN75883	14.02.2020		NL2024917

International Patent Classification (IPC)
INV. C25B1/04 H02K7/18 ADD. H02M1/14 H02M7/219

Applicant
HYGRO Technology BV

This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☐ Box No. VII — Certain defects in the application
- ☒ Box No. VIII — Certain observations on the application

	Examiner
	Standaert, Frans

WRITTEN OPINION

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	2-13
	No:	Claims	1
Inventive step	Yes:	Claims	
	No:	Claims	1-13
Industrial applicability	Yes:	Claims	1-13
	No:	Claims	

2. Citations and explanations

   see separate sheet

WRITTEN OPINION

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1 DE BATTISTA H ET AL: "Power conditioning for a wind-hydrogen energy system",
JOURNAL OF POWER SOURCES, ELSEVIER SA, CH,
deel 155, nr. 2, 21 april 2006 (2006-04-21), bladzijden 478-486,
XP027937651, ISSN: 0378-7753

D2 BINTZ STEFFEN ET AL: "Parallel-Serial-Rectifier for Power-to-Hydrogen Applications",
2019 21ST EUROPEAN CONFERENCE ON POWER ELECTRONICS AND APPLICATIONS (EPE '19 ECCE EUROPE), EPE ASSOCIATION, 3 september 2019 (2019-09-03), XP033665765,
DOI: 10.23919/EPE.2019.8915526

D3 BINTZ STEFFEN ET AL: "Load Emulation for Electrolysis Rectifiers",
2019 IEEE 13TH INTERNATIONAL CONFERENCE ON POWER ELECTRONICS AND DRIVE SYSTEMS (PEDS), IEEE, 9 juli 2019 (2019-07-09), bladzijden 1-7, XP033719305,
DOI: 10.1109/PEDS44367.2019.8998887

1 LACK OF NOVELTY

1.1 The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.

1.2 Document D1 discloses (the references in parentheses applying to this document):

"Wisselstroom AC naar gelijkstroom DC conversiecircuit voor een turbine generator (D1, abstract and Fig. 5), omvattende:
een actieve AC/DC omzetter (page 479, right-hand column, item/dot "electronic converter) met een bestuurbaar uitgangsspanningsniveau met een ingang voor ontvangen van wisselstroom elektrisch vermogen van een turbine generator en een uitgang voor leveren van gelijkstroom elektrisch vermogen aan een elektrolysesysteem voor elektrolyse van water;
een besturingseenheid (Fig. 5, and Section 2.2 starting on page 480) ingericht om:

- gegevens te ontvangen gerelateerd aan ten minste een van een staat van het elektrolysesysteem en de turbine generator (Fig. 5); en
- de uitgangsspanning aan te passen op basis van de ontvangen gegevens (Fig. 5 and page 479, right-hand column, item/dot "electronic converter)".

The subject-matter of claim 1 is therefore not new.

1.3 Furthermore, document D2 discloses (the references in parentheses applying to this document):

"Wisselstroom AC naar gelijkstroom DC conversiecircuit (D2, Figs. 1 and 5) voor een turbine generator (feature merely related to the use of the apparatus; moreover power generated by a wind turbine can be supplied to a user/ electrolyser via the grid, conform the "Introduction" on page 1 of D1), omvattende:
een actieve AC/DC omzetter (B6 Thyristor Rectifier in Fig. 1) met een bestuurbaar uitgangsspanningsniveau met een ingang voor ontvangen van wisselstroom elektrisch vermogen van een turbine generator en een uitgang voor leveren van gelijkstroom elektrisch vermogen aan een elektrolysesysteem voor elektrolyse van water (abstarct of D2);
een besturingseenheid ingericht om:
- gegevens te ontvangen gerelateerd aan ten minste een van een staat van het elektrolysesysteem en de turbine generator; en
- de uitgangsspanning aan te passen op basis van de ontvangen gegevens (currents $i_{VSL,1}$, $i_{VSL,2}$ and $i_{VSL,3}$ in Figs. 1 and 5 of D2 are calculated according to eq. (8) on top of page 6 of D2, wherein the the amplitude $\hat{I}_{si}$ is obtained from the DC-link voltage controller, or load controller. The load (electrolyser) is modelled with an equivalent electrical circuit based on the parameters provided by Table II of D2, which includes electrolyser voltage, electrolyser resistances, electrolyser capacitance and electrolyser inductance)".

The subject-matter of claim 1 is therefore not new.

2 LACK OF INVENTIVE STEP

2.1 The present application does not meet the criteria of patentability, because the subject-matter of claims 2-13 does not involve an inventive step, for the reason that the subject-matter of said claims is directly derivable from the disclosure of document D2 and/or represents simple design details which are generally known to the person skilled in the field of power converters and/or electrolysers.

2.1.1 With regard to dependent claims 2, 3, 5-7 and 13, the applicant is referred to documents D2 or D3 (see the passages cited by the search report). Furthermore, insofar these documents are not self-explaining, it should be noted that the corresponding reasoning is analogous to that provided for the dependent claims of related application SN75882.

2.1.2 Furthermore, the subject-matter of dependent claims 4 and 8-12 relates to straightforward interactions between wind turbine, rectifier, power grid and electrolyser when combined into a single system.

Re Item VIII

The term "wisselspanningssignaal" used in claim 2 does not have an antecedent basis, and seems to be mistaken for "wisselstroomhulpsignaal".