



(86) Date de dépôt PCT/PCT Filing Date: 2000/07/04
 (87) Date publication PCT/PCT Publication Date: 2001/01/11
 (85) Entrée phase nationale/National Entry: 2002/01/03
 (86) N° demande PCT/PCT Application No.: DE 2000/002169
 (87) N° publication PCT/PCT Publication No.: 2001/003223
 (30) Priorités/Priorities: 1999/07/05 (199 30 877.2) DE;
 1999/12/23 (199 62 681.2) DE

(51) Cl.Int.⁷/Int.Cl.⁷ H01M 8/24, B60L 11/18, H01M 8/04

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(54) Titre : SYSTEME DE PILE A COMBUSTIBLE ET PROCEDE PERMETTANT DE FAIRE FONCTIONNER UN TEL
 SYSTEME

(54) Title: FUEL CELL FACILITY AND METHOD FOR OPERATING A FUEL CELL FACILITY

(57) **Abrégé/Abstract:**

The invention relates to a fuel cell facility and to a method for operating a fuel cell facility comprising dynamic output regulation by connecting at least one partial system maintained ready for operation, a starter system and/or a low voltage unit for night operation and/or on-board power supply.



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Abstract

Fuel cell installation and method for operating a fuel cell installation

The invention relates to a fuel cell installation and to a method for operating a fuel cell installation with dynamic power control, by connecting up at least one subsystem which is kept ready for operation, a starter system and/or a low-voltage unit for nighttime operation and/or the on-board power supply.

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Description

Fuel cell installation and method for operating a fuel cell installation

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The invention relates to a fuel cell installation in accordance with the preamble of patent claim 1. In addition, the invention also relates to a method for operating a fuel cell installation of this type.

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A fuel cell installation which comprises a plurality of fuel cell stacks is known, for example from EP 0 677 411 B1. This document proposes that the fuel cell module be divided into a plurality of stacks for design reasons, since either the number of individual cells required would have overloaded a stack in a stationary fuel cell installation or the weight distribution of the drive unit in the vehicle required the cells to be divided into two stacks.

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The same substantially results from DE 197 03 171 A and DE 196 37 207 A, in which there are in each case two fuel cell stacks. The two stacks are operated in coordination with one another, as a single installation. Furthermore, JP 04-087262 A has disclosed an "installation for energy generation using fuel cells", in which, in addition to fuel, the exhaust gas from the first fuel cell is also introduced into the second fuel cell.

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The known designs for fuel cell installations have scarcely any way of achieving dynamic power adjustment, for example during overtaking maneuvers, since they only provide for a continuous increase in the power by means of a higher operating pressure, higher reaction-gas concentration, etc. A further drawback of the known

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systems with fuel cell installations is that neither low-voltage units nor additional units, for example for summertime and/or nighttime operation of the stationary fuel cell installation, for the on-board power supply

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or as an additional unit for dynamic operation of the mobile installation, are available.

Therefore, it is an object of the present invention to
5 provide a fuel cell installation which achieves dynamic power adjustment and/or has a low-voltage unit. A further object of the invention is to provide a method for operating an installation of this type.

10 According to the invention, the object is achieved by the features of patent claim 1. An associated method for operating a fuel cell installation of this type is given in patent claim 8. Further developments of the fuel cell installation according to the invention and
15 of the associated operating method form the subject matter of the dependent patent claims.

The invention relates to a fuel cell installation which comprises subsystems which can be operated separately
20 and at least two of which are not identical, the subsystems having separate voltage control and/or power electronics. The invention also relates to a method for operating a fuel cell installation, in which at least two subsystems are operated separately.

25 According to an advantageous configuration of the installation, the subsystems are electrically connected in series, in order to apply a maximum voltage of the system, for example when using small subsystems with a
30 large number of cells but a small electrode surface. Cells of this type are also known as "strip cells" and are distinguished by the fact that there are different potentials in the cell plane of a fuel cell unit. This context is taken into account when designing the
35 starter system. To achieve the maximum current, subsystems with the same voltage, which are inherently

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connected in series, for example by strip cells, are connected in parallel. In this way, the voltage required to drive the electric motor can be ensured irrespective of the load.

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According to an advantageous configuration of the invention, at least one sub system of the installation comprises at least one high-temperature polymer electrolyte membrane (HTM) fuel cell and/or a polymer electrolyte membrane (PEM) fuel cell.

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The terms "subsystem" denotes a stack comprising at least one fuel cell unit. A plurality of subsystems may be accommodated either in one housing or in separate housings.

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By way of example, two subsystems can be activated, operated, actuated and controlled separately, i.e. independently. Each of the subsystems provides the entire operating voltage, except that one subsystem is used only as a low-voltage unit. The independent characteristics of the subsystems encompass both the time component and the operational component, i.e. the subsystems can on the one hand be operated in succession and on the other hand in parallel with a different operating mode. A combination of the two variants, in which one subsystem is started later and is run under different operating conditions, is also included.

By way of example, a system comprises three subsystems with the following power distribution: 10 kW, 20 kW and 20 kW again. A 20 kW block is sufficient for starting, given an appropriate voltage, and if necessary the other blocks are then connected up in order to dynamically increase the power. Each subsystem provides the full starting and/or operating voltage.

According to another example, the steps are connected in parallel and/or in series: in the example, the fuel cell installation 3 has separate stacks, which can be connected in series and/or in parallel: stack 1 is used to supply the stationary current and has a low operating voltage (number of electrodes) and a medium power output (electrode surface area), stack 2 has a higher number of electrodes (voltage) and likewise a medium power output, and finally stack 3 has the full operating voltage with a high power output, but it takes a long time for it to reach operating temperature. If stacks 1 and 2 are connected in series, they also provide the full operating voltage, i.e. the voltage which the system needs to start and which, for example, corresponds to the voltage of the stack 3;

although they cannot provide the ultimate output (with regard to current/electrode surface area) of the system, they quickly reach operating heat and are ready for use. Stacks 1 and 2 connected in series are able to
5 start the vehicle, and

as soon as stack 3 has reached its operating temperature it takes over the driving, while stack 1 and stack 2 are switched off or can, for example during overtaking maneuvers, be switched on again, while stack 5 1 can be used separately for on-board power supply if the total power of all three stacks is not required for driving. For operation on the expressway, it is even possible for stacks 1 and 2, connected in series, to be connected in parallel with stack 3, in which case all 10 the electrode surfaces of the three separate stacks would be used to generate power and to drive the vehicle.

According to a further example, the system comprises 10 15 subsystems, each providing 5 kW. This makes maintenance/repair work particularly easy, since the individual systems are small and easy to exchange in the event of faults/maintenance.

20 Depending on requirements, a subsystem which can be switched on may comprise conventional fuel cells (large-area, high-amp fuel cell) or strip cells (small area, high voltage when connected in series), in which case the requirement may either be a higher voltage or 25 more current.

According to the invention, the subsystems may or may not be identical. In particular, they may or may not be identical with regard to power, size, material, output 30 and/or type of fuel cell, such as for example conventional fuel cell (uniform potential on the baseplate) and/or strip cell (different potentials on the baseplate); PEM, HTM fuel cell, PAFC (Phosphoric Acid Fuel Cell) fuel cell, MCFC (Moten Carbonate Fuel 35 Cell), DMFC (Direct Methanol Fuel Cell) and/or SOFC (Solid Oxide Fuel Cell) fuel cell.

If it is desired for the power output of the subsystems

to be connected in parallel/optimized and there is a considerable difference in size between the subsystems, the use of strip

cells, in which the electrical cell surface is reduced in size, is preferred.

The term can be operated separately is understood as meaning that the subsystems can be activated and kept running independently, i.e. separately. The subsystems are activated, for example, by cooling, by the supply of process gas and/or electrically. In this case, one subsystem can preheat the other, for example by means of its exhaust gas.

HTM fuel cells are known from the parallel application bearing the same name, filed by the same applicant, the content of which is hereby referred to in its entirety.

An HTM (high-temperature polymer electrolyte membrane) fuel cell, also known as an HTM fuel cell unit, comprises the following components

- a membrane and/or matrix,
- 20 - which contains a self-dissociating and/or autoproteolytic electrolyte in chemically and/or physically bound form,
- two electrodes, which are on opposite sides of the membrane and/or matrix,
- 25 - adjacent to at least one electrode, a reaction chamber which is closed off from the environment by in each case a terminal plate and/or a corresponding edge structure, devices which can be used to introduce and discharge the process gas into and from
- 30 the reaction chamber being provided,
- the structural components of the HTM fuel cell being formed in such a way that they are able to withstand reduced pressure down to approx. 0.3 bar and temperatures up to 300°C for a prolonged period.

35 According to an advantageous configuration of the method, the fuel cell installation is run in combined continuous and discontinuous operation, i.e. within an

operating phase, at least one further subsystem can be switched on quickly for power peaks, so that good power dynamics for use of the installation in mobile and stationary systems are produced.

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To make the cold start easier, according to one embodiment at least one small subsystem, e.g. a low-voltage system as heating, is run in permanent operation, so that it either keeps the operating
10 temperature or some other temperature above the crystallization point of the electrolyte (e.g. above 40°C) and can then be used to heat up the remaining subsystems in order for the installation to start. In the configuration of the method in which a subsystem is
15 run in permanent operation, this subsystem is preferably operated with maximum thermal output at least during the inoperative phase, in which it is used to maintain the minimum temperature (e.g. for an autothermal starting operation). The term inoperative
20 phase is used to indicate the time during which the fuel cell system is switched off.

Depending on requirements, the efficiency of the subsystem may be controlled toward higher current
25 generation or higher thermal output by setting the cell voltage. The control may in this case also take place by means of a control unit in accordance with a predetermined algorithm, taking account of a number of measurement data and/or of the desired current output,
30 heating output and/or the driver's wishes, etc. Setting to achieve a higher thermal output is preferably used to maintain the operating temperature.

In one configuration of the method, although the
35 "starter system" is not run in permanent operation, either, during a cold start, initially only this relatively small subsystem is heated, or a temperature

which is higher than the crystallization point of the electrolyte is reached in the subsystem by means of insulation, a latent heat store and/or heating, so that autothermal heating of the starter system

can take place. In this case, it is advantageous if there is a PEM/HTM system combination, in which the PEM system is the starter system, since the PEM system can be started autothermally even at temperatures which are
5 only just above 0°C, whereas an HTM system with a brösted acid, such as for example phosphoric acid, as electrolyte can only be started autothermally at temperatures of over 40°C. It is also possible to provide an additional energy store, such as a battery,
10 for standby mode.

The term "starter system" denotes the subsystem which allows partial load operation which, during the transition to the next, higher load phase (switching on
15 further subsystems) and/or during the transition to full-load operation, heats up further subsystems both by means of the waste heat and by means of electrical power output, and these subsystems can the be connected
up.

20 Irrespective of the starter system, according to an advantageous configuration an additional energy store, such as for example a battery, is provided, which, for example in the case of mobile applications, provides
25 the drive unit with the energy required for starting and at least 3-5 minutes of driving time.

The waste heat from a smaller subsystem, for example the waste heat from the low-voltage or starter system,
30 can be used to heat the inhabited room or passenger compartment.

According to an advantageous configuration of the fuel cell installation and of the operating method, a modular
35 media preparation means is provided, so that the peripherals of the installation, such as for example fuel cell stack, reformer, compressor (blower) and fan can each be operated in their optimum operating range.

Accordingly, the units in the stack peripherals can be in the form of a plurality of modules comprising smaller units, so that, for example, during partial-load operation of a fuel cell stack, one
5 reformer module of a number of such modules

is operated at full load, each of the appliances then running in their optimum operating range, i.e. with optimum utilization of fuel.

- 5 The mean size of an HTM or PEM fuel cell subsystem in a fuel cell installation which is used for electrical traction comprises, for example, 300 fuel cell units for electrical traction.
- 10 A starter system supplies the voltage which is required for starting, e.g. 100-500 V, preferably 200 V; an output in the range from 1 to 35 kW, in particular between 10 and 20 kW, is sufficient. According to one embodiment, the starter system at least in part
- 15 comprises strip cells, so that the required voltage can be produced within a small space.

A system which is used for the low-voltage on-board power supply (e.g. the 42 volt vehicle electrics

20 system) comprises, for example, 20 - 60 fuel cell units and has a maximum output of approx. 1 to 10 kW.

During starting and/or during the inoperative phase during which the operating temperature is maintained

25 (maintenance load) and/or during an operating phase involving a low load (idling), it is appropriate for the cooling to be connected in series, so that the cooling of one subsystem can be used as heating for another subsystem. In this case, it is also

30 advantageous if, in the case of air operation, a plurality of stacks are connected in series, so that the waste air from the first stack can be used to heat the next stack. Connecting the stacks in series may also be advantageous during single-stack operation of

35 the multistack system, since the heat from the waste air from the stack which is operating is used to maintain the operating temperature of the stack which is currently not operating. The installation of an air

filter for cooling and/or reaction air is advantageous.

According to one configuration of the installation, at least two subsystems comprise HTM fuel cells. In this embodiment, it is preferable for the cooling of the two subsystems, when the operating temperature has been reached, to be connected in parallel, since the two subsystems are at the same operating temperature.

In the case of subsystems with a similar or identical operating temperature, it is preferred for the cooling to be connected in parallel during normal operation.

At temperatures of below 120°C and/or on account of the emissions limits which have to be observed, gas cleaning is preferably provided in an HTM subsystem with reformer, in order to remove CO from the process gas or to reduce the CO content of the residual gas.

According to one configuration of the installation, at least one subsystem comprises at least one HTM fuel system and a subsystem comprises at least one polymer electrolyte membrane (PEM) fuel cell.

In this configuration, when the operating temperature has been reached, the cooling of the two subsystems can be connected in series, since the heated cooling medium from the PEM fuel cell subsystem is still cool enough to cool the subsystem with HTM fuel cells, which are operated at a considerably higher temperature.

It is also possible, in the combination of at least one PEM fuel cell subsystem with an HTM fuel cell subsystem, to provide a two-part cooling system, which comprises a low-temperature cooling circuit and a high-temperature cooling circuit. In the case of a PEM fuel cell subsystem, CO gas cleaning, for example in the form of a hydrogen-permeable barrier membrane, is provided.

This combination is particularly suitable for an installation with on-board power supply, the PEM subsystem preferably being used for the low-voltage on-board power supply.

5

According to an advantageous configuration of the method, the fuel cell installation is dried by heating during the inoperative phase, so that, for example during short-time operation, when inoperative and/or
10 load phases are short, the stack temperature is essentially kept above the boiling point of water. This can be achieved, for example, by setting a maintenance load during the inoperative phase. The maintenance load set can preferably be adjusted, so that it is possible
15 to distinguish between the fuel cell installation being switched off for three weeks or three hours.

According to another configuration of the method, when the installation is shut down, at least one subsystem
20 and/or a cooling system is blown through and/or blown dry - either in combination with the drying by heating or as a stand-alone measure - using process gas and/or inert gas, so that during starting the installation is as free from water as possible and/or the cooling
25 system is as empty as possible. Emptying of the cooling system is in this case completely independent of the drying of the stack by blowing it dry.

Ongoing monitoring of the water content of the emerging
30 process gas and/or inert gas during the blowing-dry operation indicates when the cell/the stack is dry and the blower or compressor can be switched off. Then, the control mechanism which is used to admit the air for the blowing-dry operation is preferably closed, and in this
35 way the stack is shut off from any atmospheric humidity.

The cooling medium which is stored externally during the inoperative phase according to one variant of this

configuration of this method can be heated externally,
during starting and/or before starting, for example by
a stack of the installation which is provided for this
purpose, by utilization of waste heat and/or by means
5 of a latent heat store,

and can be admitted as heating medium to the cooling system of a subsystem which is to be started.

5 The blower required for this purpose may be the compressor and is supplied, for example, with power from the and/or another subsystem of the fuel cell installation and/or via an external energy store, in particular an electrical energy store.

10 A subsystem of the fuel cell installation may be provided for the purpose of supplying starting current, for example for supplying the units such as heating for process-gas preheating, compressor, reformer, blower, etc.

15 The term fuel cell installation is used to denote the entire fuel cell system, which at least two subsystems, which either form two separate stacks or are integrated in a housing. The subsystems each have at least one
20 fuel cell unit, the corresponding process-gas feed and discharge ducts, the end plates, the cooling system with cooling medium and all the fuel cell stack peripherals (reformer, compressor, blower, heating for process-gas preheating, etc.).

25 The term stack denotes the stack comprising at least one fuel cell unit with the associated lines and at least part of the cooling system.

30 A fuel cell unit comprises at least one membrane and/or matrix with a chemically and/or physically bound electrolyte, two electrodes, which are on opposite sides of the membrane and/or matrix, adjacent to at least one electrode a reaction chamber, which is closed off from
35 the environment by in each case a terminal plate and/or a corresponding edge structure, devices which can be used to introduce and discharge the process gas into and from the reaction chamber being provided.

The fuel cell installation according to the invention allows, for example, differentiated power output, which can be dynamically adjusted to the particular conditions, from the installation. Moreover, a
5 subsystem may be provided for connecting up only when accelerating, this subsystem, while it is inoperative, always being kept at operating temperature by means of the cooling circuit of another subsystem, which is operating, by means of a latent heat store or by means
10 of some other device (heating, insulation, maintenance load). Latent heat stores for more rapid heating of the cooling water in motor vehicles are known. The storage media used are what are known as phase change materials, such as barium hydroxide, etc. The heat
15 uptake or dissipation is effected by melting or recrystallization of the materials.

A further option which is opened up for the first time by the system is for a subsystem to be designed as a
20 "low-voltage unit" or "starter subsystem" for summertime or nighttime operation, for starting and/or for on-board power supply (continuous current heating, air-conditioning unit, heating, radio, etc.) as an APU (Auxiliary Power Unit). This subsystem can then be
25 operated with a low rated output, for example 1 - 50 kW (corresponds to approx. 5 to 20% of the rated output of the overall system). By its nature, the starter system differs from the low-voltage unit through the voltage which is produced, since the starter system supplies
30 the volts which the vehicle needs in order to start up.

Patent claims

1. A fuel cell installation having at least one fuel cell stack comprising individual fuel cell units which are connected electrically in series and each form a subsystem of the fuel cell installation, characterized in that there are separate subsystems, of which at least two subsystems are not identical and have a separate voltage control and/or power electronics.
2. The fuel cell installation as claimed in claim 1, characterized in that at least two subsystems are connected electrically in parallel.
3. The fuel cell installation as claimed in one of the preceding claims, characterized in that at least one subsystem of the installation is present at least one high-temperature polymer electrolyte membrane (HTM) fuel cell unit, a strip cell and/or a polymer electrolyte membrane (PEM) fuel cell unit.
4. The fuel cell installation as claimed in one of the preceding claims, characterized in that at least one starter system and/or a low-voltage unit is present.
5. The fuel cell installation as claimed in claim 6, characterized in that the starter system comprises at least one PEM fuel cell unit.
6. The fuel cell installation as claimed in one of the preceding claims, characterized in that at least two subsystems with two cooling circuits, which can be connected in series and/or in parallel, are present.

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7. The fuel cell installation as claimed in one of the preceding claims, characterized in that an additional energy store, for example a battery, is provided.
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8. A method for operating a fuel cell installation as claimed in patent claim 1 or one of claims 2 to 7, in which at least two subsystems are activated and/or operated separately.
- 10
9. The method as claimed in one of claims 3 to 10, which the operation of the subsystems takes place in continuous and discontinuous operation.
- 15
10. The method as claimed in one of claims 8 or 9, in which at least one starter system is started at the beginning of the cold starting of the fuel cell installation.
- 20
11. The method as claimed in one of claims 8 to 10, having a modular media preparation means, which ensures optimum utilization of the fuel gas.
- 25
12. The method as claimed in one of claims 8 to 11, in which, during the inoperative phase, at least one low-voltage and/or a low-current subsystem is operated under maintenance load.
- 30
13. The method as claimed in one of claims 8 to 12, in which, during starting and/or during the inoperative phase under maintenance load, and/or an operating phase with a low load, the cooling of the stacks is connected in series.
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14. The method as claimed in one of claims 8 to 13, in which fuel cell installation is dried during the

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inoperative phase by heating and/or or by being
blown dry and is shut off from atmospheric
humidity as a result of the valves/flaps being
closed.

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15. The method as claimed in one of claims 8 to 14, in which, by setting the cell voltage, the efficiency of a subsystem is set toward a higher voltage or a higher thermal output.

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