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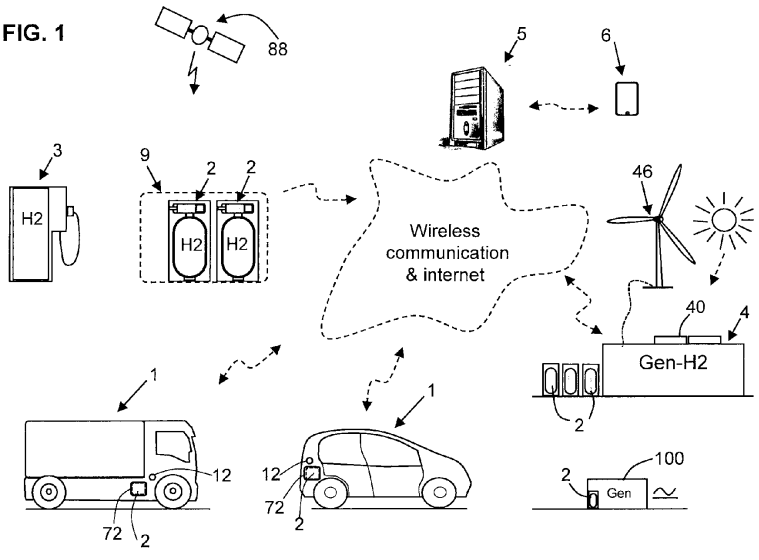
(54) **HYDROGEN BASED SYSTEM, RELATED MANAGEMENT SYSTEM AND RELATED METHOD**

(57) A system based on hydrogen fuel, the system comprising vehicles (1) each powered by a fuel cell (70) with a hydrogen supply comprising one hydrogen cartridge (2), the hydrogen cartridge being removably mounted in the vehicle, the system comprising a plurality of stationary hydrogen cartridges, available at hydrogen relay spots (9), wherein each of the hydrogen cartridges comprises a pressurized bottle and a head device including pressure and temperature sensing means, geolocating means and communication means to transmit cartridge data to a remote server (5) comprising a server application configured to collect and gather data about hydrogen cartridges, to build therefrom a map of hydrogen resources, wherein the server downloads updated cartographic data to client applications, with current hydrogen resources available, including geolocation and particulars of hydrogen cartridges.

FIG. 1



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Description

FIELD OF THE DISCLOSURE

[0001] The instant disclosure relates to hydrogen-based systems. Such hydrogen-based systems are generally energy-driven systems, notably transportation systems. Such systems involve vehicles comprising an electric driveline moved by a fuel cell device supplied from a pressurized hydrogen reservoir arranged aboard the vehicle. The vehicles at stake here are passenger cars, light trucks, city cars, electric motorcycles, without excluding other types, like all kinds of terrestrial vehicles including railway vehicles. Such systems can also involve stationary electric generators using a hydrogen reservoir as a fuel source.

BACKGROUND OF THE DISCLOSURE

[0002] The pressurized hydrogen reservoirs of the above vehicles are to be refilled at refilling stations. Currently, the number of available refilling stations is rather low (let's say about 40 in France and 250 in overall Europe in early 2023). Furthermore, such refilling stations involve complex and expensive arrangements to ensure the safety of operation in all circumstances. As a matter of fact, at refilling stations, the hydrogen gas (H_2) is supplied at pressures such as 350 bar and 700 bar.

[0003] Therefore, the low availability of hydrogen gas resources across territories is a critical hindrance regarding the development and use of hydrogen-based transportation vehicles.

[0004] Meanwhile, there is a strong trend towards zero-emission vehicles, and battery electric vehicles exhibit some drawbacks, like among others the large time required to recharge the batteries.

[0005] The inventors have sought to give a new opportunity to the development of hydrogen-based systems notably hydrogen-based transportation vehicles.

SUMMARY OF THE DISCLOSURE

[0006] According to one aspect of the present disclosure, it is disclosed a system for carrying out transportation of people and/or goods based on hydrogen fuel, the system comprising a plurality of vehicles (1), each powered at least by a fuel cell, each vehicle comprising a hydrogen supply comprising at least one onboard hydrogen cartridge (2), the onboard hydrogen cartridge being removably mounted in a vehicle structure,

the system comprising a plurality of stationary hydrogen cartridges, available at a plurality of hydrogen relay spots (9), distributed across a geographical area,

wherein each of the onboard and stationary hydrogen cartridges comprises a pressurized bottle and a head device including pressure and temperature sensing means, geolocating means and communication means to transmit cartridge data, at least partly wirelessly, to a remote server (5) comprised in the system,

the server comprising a server application (50) configured to collect and gather data about onboard and stationary hydrogen cartridges,

wherein the server application is configured to build therefrom a map of hydrogen resources across the geographical area,

wherein the server is configured to download updated cartographic data to at least a client application (60,55), said updated cartographic data comprising current hydrogen resources available across the geographical area, including geolocation and particulars of at least each stationary hydrogen cartridge.

[0007] Thanks to this system, the promoted shared knowledge of available hydrogen resources in the concerned geographical area allows an easy and dependable operation of many hydrogen-based vehicles in a cost-effective manner, even though the geographical coverage with hydrogen refilling stations is still very poor. The promoted system is also applicable, besides vehicles, to stationary hydrogen gas consumer devices.

[0008] It is to be noted that the system can also include stationary use devices (i.e. stand-alone electrical generators) supplied by hydrogen fuel instead of being supplied by fossil fuel, or bikes/scooters recharging stations not supplied from the electric public grid.

[0009] Here the term *"hydrogen cartridge"* is to be understood as a reusable hydrogen gas unit or otherwise hydrogen gas module, that can be refilled, and easy to handle and couple to a counterpart device.

[0010] The term *"relay spot"* is to be understood as a small facility, indoors or outdoors, housing one or more hydrogen cartridge(s). As will be seen, this facility may comprise compartments and lockers.

[0011] In the present disclosure, the locution *"pressurized bottle"* is equivalent to *"pressurized reservoir"* otherwise designating a small portable tank.

[0012] In the present disclosure, the term *"particulars"* means relevant data about hydrogen cartridges including at least their current filling percentage. Current temperature and current pressure can be part of these particulars.

[0013] In addition to geolocation and particulars of at least each stationary hydrogen cartridge, the so-called updated cartographic data comprising current hydrogen resources can also comprise geolocation and particulars of the onboard hydrogen cartridges. Fleet managers can see at a glimpse where the vehicles are located and the remaining quantity of hydrogen in each bottle in the vehicles.

[0014] The updated cartographic data gives a synthetic view of hydrogen resources; this synthetic view is made available to various people and processes: vehicle drivers, vehicle fleet managers, remote and on-

board itinerary planner engines, and would-be hydrogen users,....

[0015] According to one aspect, all the onboard and stationary hydrogen cartridges share a single mechanical interface and a single fluid interface for interoperably coupling each of them to each one of the plurality of vehicles. This advantageous feature of interfaces ensures full interoperability between all cartridges and all user devices as well as bottle refueling stations. The single fluid interface is also compatible with stationary use devices.

[0016] According to a further aspect, each hydrogen relay spot is configured to accommodate one or more stationary hydrogen cartridges and the stationary hydrogen cartridges can be lockably secured in lockers at the hydrogen relay spot. Such a feature allows to protect hydrogen cartridges from the environment, and this allows securitization of hydrogen cartridges at hydrogen relay spots. Only an authorized subscriber can take hydrogen cartridges from the relay spot.

[0017] According to a further aspect, each hydrogen cartridge comprises a generally parallelepiped protective casing, said protective casing encompassing the pressurized bottle and the head device therein. This provides appropriate mechanical protection against shocks and crashes. This helps to fulfil compliance with regulatory requirements.

[0018] According to one aspect, the system may further comprise a plurality of refilling stations (such stations can also be named 'refueling stations'), distributed across the geographical area, wherein the map of hydrogen resources across the geographical area also includes the geolocation and particulars of each refilling station. This complements the comprehensive vision of hydrogen resources for end users, fleet managers, and system maintenance officers.

[0019] According to a further aspect, the system may further comprise a plurality of hydrogen gas-producing devices such as electrolysis, vaporeforming or pyrolysis devices for producing hydrogen, distributed across the geographical area, wherein the map of hydrogen resources across the geographical area also includes the geolocation and particulars of each H_2 production device. This complements the comprehensive vision of hydrogen resources for end users, fleet managers, and system maintenance officers.

[0020] According to a further aspect, one or more of the vehicles comprises a display (14). Vehicle drivers can be made aware of nearby hydrogen relay spots on a navigation map. In addition, the vehicle driver can also use a smartphone application as a display function.

[0021] According to a possible option, one or more of the vehicles comprises a refill port (12). The onboard hydrogen cartridge can be refilled in situ, i.e. without exchanging hydrogen cartridges.

[0022] According to a further aspect, the fluid interface between the vehicle and the onboard hydrogen cartridge (s) includes a quick connect/disconnect coupling interface (80). The fluid coupling is therefore made simple and easy.

[0023] According to a further aspect, the head device comprises a battery, with an electrical storage capacity comprised between 3000 mAh and 9000 mAh.

[0024] According to a further aspect, the head device comprises an accelerometer to determine accelerations and shocks possibly undergone by the hydrogen cartridge.

[0025] According to one aspect, the communication means to transmit cartridge data comprises a LoRa or Sigfox coupler. Thereby the system uses cost-effective and large coverage IOT communication network.

[0026] According to another option, said communication means comprises a WLAN coupler. We can thereby take profit from the available cellular hotspots in the surroundings.

[0027] According to another option, said communication means comprises a LTE coupler or a 5G coupler. Thereby, a high bandwidth capability is available.

[0028] According to one aspect, the head device comprises a unique identifier for each hydrogen cartridge. Each hydrogen cartridge can be individually recognized and the data about a cartridge cannot be mixed with another one. Managing the complete set of cartridges is therefore reliable. It is also possible and easy to add new hydrogen cartridges to the system having their own unique identifier.

[0029] According to one aspect, the unique identifier is transmitted within each uplink communication from a head device to the server. Therefore, from the server viewpoint, the data coming from the field can be unambiguously allocated to the proper hydrogen cartridge.

[0030] According to one aspect, the cartridge data may comprise : a unique cartridge identifier, current pressure, current temperature, current geolocation, current charge of local electric battery. The server may therefore collect and update the basic information about each cartridge.

[0031] According to one aspect, the cartridge data may comprise : a H_2 traceability information, a date of last maintenance inspection. The server may therefore monitor the lifecycle of each cartridge.

[0032] According to one aspect, the payload capacity of each hydrogen cartridge is preferably comprised between 400 grams and 1 Kg of hydrogen gas. Such a mass provides substantial miles of autonomy. According to a possible option, the payload capacity is more preferably comprised between 600 grams and 750 grams. For a passenger vehicle, 1 Kg of H_2 enables generally a 100 km range.

[0033] According to one aspect, the weight of each hydrogen cartridge is less than to 30 Kilograms. Such hydrogen cartridges can be handled with a simple assistance handling system by one person or by two staff members with no assistance device.

[0034] According to one aspect, the weight of each hydrogen cartridge is less than 25 Kilograms This allows manual handling by some end users or by one authorized

staff member without particular assistance.

[0035] The present invention is also directed to a method for implementing and operating a transportation system based on hydrogen fuel, the system comprising a plurality of vehicles, each powered at least by a fuel cell, each vehicle comprising a hydrogen supply, the method comprising :

- providing a plurality of hydrogen cartridges, wherein each of the hydrogen cartridges comprises a pressurized bottle and a head device including pressure and temperature sensing means, geolocating means and communication means to transmit cartridge data remotely to a server,
- providing, in one or more vehicles, a reception area (72) to receive at least one onboard hydrogen cartridge, and a releasable coupling to fluidly couple the pressurized bottle to the vehicle fuel cell, whereby the hydrogen cartridge forms the vehicle hydrogen supply,
- providing a plurality of hydrogen relay spots, distributed across a geographical area, each hydrogen relay spot being adapted to accommodate one more hydrogen cartridges, .
- providing a server application configured to collect and gather data about hydrogen cartridges,
- building therefrom a map of hydrogen resources across the geographical area,
- downloading updated cartographic data to at least a client application, said updated cartographic data comprising current hydrogen resources available across the geographical area, including geolocation and particulars of each stationary hydrogen cartridge.

[0036] According to one aspect, the method further comprises a sequence of cartridge exchange, said sequence comprising:

x1- fluidly uncoupling the onboard hydrogen cartridge installed in the reception area,
x2- removing the onboard hydrogen cartridge from the reception area,
x3- getting access to a new hydrogen cartridge from a hydrogen relay spot,
x4- installing the new hydrogen cartridge in the reception area, thereby becoming a new onboard hydrogen cartridge,
x5- fluidly coupling the new hydrogen cartridge to the vehicle fuel cell,
x6- placing the former onboard hydrogen cartridge in one position at the hydrogen relay spot.

[0037] According to one aspect, at step x3-, authentication is required to allow access to the new hydrogen cartridge. Thereby, only an authorized user can take hydrogen cartridge from the hydrogen relay spot. Unauthorized persons are prevented to have access or tempering the hydrogen cartridge.

[0038] According to one aspect, the map may pinpoint the geolocation and particulars of each hydrogen cartridge, possibly each refilling station, and possibly each electrolysis device or any H_2-producing apparatuses. This makes the use of the system easy and intuitive for vehicle drivers, staff members, and maintenance officers.

[0039] According to one aspect, each vehicle may comprise a management unit (13) and wireless communication means to make available the currently available miles autonomy to the server, wherein the server application and/or the vehicle management unit is configured to calculate a list of hydrogen relay spots within reach of the vehicle and at least the number of fully filled hydrogen cartridges available at each hydrogen relay spot of said list.

[0040] According to one aspect, the server application provides a list of collect and refilling orders to a fleet staff member, said collect order prompting to collect emptied hydrogen cartridge(s) at the hydrogen relay spots, and to proceed with a refilling step. This allows easy management of the ecosystem.

[0041] According to one aspect, furthermore, the server application could be used to build a map of other gas resources (biomethane, medical oxygen, food CO_2, etc.).

[0042] According to one aspect, the server application provides a list of resupply orders to a fleet staff member, said resupply order prompting to bring full hydrogen cartridge(s) to hydrogen relay spots. This allows easy management of the ecosystem.

[0043] According to one aspect, the server application is provided with future ordered transportation missions, and the server application calculates an anticipated map. Not only the current situation is comprehensively presented to the users, but also foreseeable future situations.

[0044] According to one aspect, the server application provides a first map content for a vehicle user, and a second map content for a fleet manager. According to an alternative solution, it can be provided data filters at the client application to choose which kind of information should be displayed or not. Therefore, users can customize the displays to their needs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] Other features and advantages of the invention appear from the following detailed description of its embodiments, given by way of non-limiting example, and with reference to the accompanying drawings, in which:

- Figure 1 illustrates diagrammatically an overview of the promoted system,
- Figure 2 shows a schematic block diagram of the system aboard a vehicle,
- Figure 3 illustrates an elevation view of an exemplary hydrogen cartridge,

- Figure 4 shows a detailed view of an exemplary head device of the hydrogen cartridge,
- Figure 5 illustrates diagrammatically data collection flow around an application server,
- Figure 6 illustrates an example of a displayed map exhibiting the hydrogen resources and vehicles
- Figure 7 illustrates an example of a hydrogen relay spot with available hydrogen cartridges awaiting future use or deposited after use,
- Figure 8 shows a schematic block diagram of the head device system.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0046] In the figures, the same references denote identical or similar elements. For the sake of clarity, various elements may not be represented at scale.

General overview

[0047] Figure 1 shows an exemplary system according to the present disclosure. The promoted system is generally a hydrogen-based system. The promoted system comprises a plurality of vehicles **1.** Each vehicle **1** is powered by a fuel cell **6** and comprises a hydrogen supply. The hydrogen supply comprises an onboard hydrogen cartridge **2,** the onboard hydrogen cartridge is removably mounted in the vehicle. It is not excluded to provide more than one removably mounted onboard cartridge(s) in the vehicle. It is also not excluded to have in addition one auxiliary hydrogen reservoir, permanently arranged in vehicle 1.

[0048] One or more vehicles 1 can comprise an internal combustion engine or a combination of electric engine and the fuel cell.

[0049] In the illustrated exemplary system, the vehicles at stake here are passenger cars and light trucks. Of course, the invention is not limited to a particular type of vehicle. The vehicles can be city cars, buses, heavy-duty vehicles, electric motorcycles, electrical bikes, and railway vehicles.

[0050] The promoted system can also include stationary electric generators **100** using a hydrogen reservoir 2 as a fuel source. The promoted system can also include any type of stationary use devices supplied by hydrogen fuel instead of being supplied from fossil fuel or from the electric public grid, for example, a remotely placed recharge station for electric bikes, away from the electric public grid.

[0051] In addition, the system comprises a plurality of hydrogen relay spots **9,** disseminated and distributed across a geographical area **GZ.**

[0052] Each hydrogen relay spot 9 comprises a plurality of hydrogen cartridges 2, here called 'stationary' hydrogen cartridges. Some of the cartridges are completely filled ('full') and ready to use, other cartridges may be empty or partly filled, e.g. after use.

[0053] The stationary hydrogen cartridges are identical to onboard hydrogen cartridges.

[0054] Here the hydrogen cartridge is a reusable hydrogen gas unit or otherwise hydrogen gas module, that can be refilled, and easy to handle and couple to a counterpart device. Here the hydrogen cartridges are all interchangeable. All the onboard and stationary hydrogen cartridges **2** share a single mechanical interface and a single fluid interface.

Hydrogen cartridges

[0055] As depicted in figures 3 and 4, each of the onboard and stationary hydrogen cartridges **2** comprises a pressurized bottle **24** and a head device **22.** The head device **22** forms a cap for the bottle. The head device **22** includes pressure and temperature sensing means. The head device **22** comprises an electronic unit **27** with a PCB and a processor. On the electronic unit 27, there is provided geolocating means and communication means to transmit cartridge data, the details thereof will be given later.

[0056] More precisely, there is provided a temperature sensor **28** and a pressure sensor **29,** both wiredly connected to the electronic unit **27.** The temperature sensor **28** can be a thermistor, whose resistance varies according to a prevailing temperature such as a CTN resistor.

[0057] The pressure sensor **29** is chosen to measure pressures up to about 500 bars.

[0058] As also apparent from figure 8, the head device **22** comprises an accelerometer **21** to sense accelerations and inertia forces undergone by the hydrogen cartridges **2.** The accelerometer **21** can be a 3-axis or a 6-axis accelerometer. The accelerometer **21** is preferably a MEMS component arranged on the PCB.

[0059] The head device **22** comprises an internal battery **82** to supply the electronic unit **27.** The battery **82** exhibits a capacity of at least 3000 mAh. The battery **82** can be of a rechargeable type. The voltage of the battery can reflect the current state of charge of the battery **82.** The current percentage of battery charge can be made available to the remote server.

[0060] The head device **22** may comprise a switch **83** to disconnect the battery **82.** There may be provided a protection fuse.

[0061] The head device **22** comprises at least one LED **53.** The LED is lighted briefly to reflect the current status of the head device. There may be provided two LEDs.

[0062] The head device **22** comprises an input **54** for acquiring the status of an electro-valve (said electro-valve is controlled by a device external to the head device **22**).

[0063] The communication means may comprise a 5G or **LTE** coupler **51**. The head device **22** comprises an antenna **52.** In other embodiments, the communication means may comprise a LoRa or Sigfox coupler. In other embodiments, the communication means may comprise a WiFi/WLAN coupler.

[0064] The head device **22** comprises a geolocation

receiver **56** for receiving the signals from satellites.

[0065] We note here that geolocation receiver **56** and wireless coupler **51** can be combined in a single component.

[0066] The head device **22** comprises at least a USB port or a CAN port **77.** In some lifetime cases the head device **22** is electrically connected to another device, like for instance a refuelling/refilling device (in such case the switch **83** may be turned off).

[0067] The USB port **77** can also be used to recharge the internal battery **82.**

[0068] There may be provided an electrical connector (not shown) to couple the head device to an internal device.

[0069] The head device **22** is configured to transmit cartridge data, at least partly wirelessly, to a remote server **5** comprised in the system.

[0070] According to embodiments, as understood from the foregoing, cartridge data may comprise: unique cartridge identifier, current pressure, current temperature, current geolocation, current charge of local electric battery **82.**

[0071] Further, cartridge data may comprise in addition: number of refills undergone, H_2 traceability information, date of last maintenance inspection. The H_2 traceability information may include an indication about the production process of the enclosed hydrogen gas (Electrolysis, Vapo-reforming and Pyrolysis from waste, other method, etc). From this information, the carbon footprint can be assessed from the user standpoint.

[0072] When the cartridge is awaiting at a hydrogen relay spot **9,** in order to preserve large electrical autonomy of the battery **82,** the data transmission occurs on a low periodic scheme, like for instance every four hours.

[0073] When the hydrogen cartridge is connected, for example under refuelling process, the period to transmit data is much smaller, to allow faster updates.

[0074] When the hydrogen cartridge is aboard a moving vehicle, the period to transmit data can also be smaller, to allow faster updates. The accelerometer **21** provided in the head device **22** can be used to shorten the period of data transmission whenever the vehicle is moving.

[0075] The head device **22** comprises a safety valve **25.** The safety valve may be a Temperature and Pressure Relief Device (TPRD in short). The safety valve may open in case the interior pressure exceeds 500 bar or if the interior temperature exceeds about 100°C.

[0076] The head device **22** comprises a stepdown pressure regulator and a quick coupling port **23** forming a quick connect/disconnect coupling interface **80** with a counterpart device.

[0077] Each hydrogen cartridge **2** comprises a generally parallelepiped protective casing **20,** said protective casing encompassing the pressurized bottle and the head device **22** therein. The protective casing **20** is made of hard plastics. The protective casing **20** provides mechanical protection against shocks and crashes for the pressurized bottle. The protective casing **20** comprises opening(s) to access at least the quick coupling port **23.** The protective casing comprises opening(s) to let access to the user's hand thereby forming one or more handle(s) integrated in the casing.

[0078] The protective casing comprises six faces: a bottom face, four long faces, and a top face. In the illustrated example bottom face and top faces are delimited by square borders, and long faces are delimited by rectangular borders.

[0079] The hydrogen cartridge **2** can be laid down on the ground on its bottom face or on any of the long faces. On these faces, the hydrogen cartridge **2** rests in a very stable manner.

[0080] The electronic unit of the head device **22** comprises a unique identifier for each hydrogen cartridge.

[0081] The payload capacity of each hydrogen cartridge is comprised between 400 grams and 1 Kg of hydrogen gas. Preferably, the payload capacity is comprised between 600 grams and 750 grams. The weight of each hydrogen cartridge is less than 30 Kilograms. The weight of each hydrogen cartridge may be about 27 Kg. This allows manual handling by some end users without particular assistance or few assistance, i.e. without a hoisting tool, still remaining in acceptable ergonomic and safety conditions.

[0082] As illustrated in figure 3, the height **H2** of the cartridges can be comprised between 700mm, and 900mm, and the width **W2** can be comprised between 300mm, and 500mm. **W2** may be comprised between 360mm and 440mm.

[0083] The pressurized bottle **24** is formed as a cylindrical enclosure with a thick cylindrical wall. The thickness of the cylindrical wall is comprised between 30mm and 50mm.

[0084] The pressurized bottle **24** can withstand pressures up to 1000 bars. The nominal service pressure is 700 bars.

[0085] Turning back to figure 1, the system further comprises a plurality of refilling stations **3,** distributed across the geographical area **GZ.**

[0086] In the illustrated example, the system further comprises plurality of H_2 production devices (Electrolysis, Vapo-reforming and Pyrolysis) **4,** distributed across the geographical area **GZ.** For example for electrolysis, devices preferably rely on windmills **46** or solar photovoltaic panels **40** to produce hydrogen gas from water. Some or all H_2 production devices **4** are configured to supply hydrogen gas at high pressure in pressurized bottles, such as those in the promoted interchangeable hydrogen cartridges **2.** H_2 generating apparatuses are considered like Electrolysis, Vapo-reforming and Pyrolysis from waste (wood, plastic, etc.) for energy recovery.

[0087] Therefore, one can say that it is provided herein a complete ecosystem, free of fossil fuel and favouring decarbonisation.

[0088] The system further relies on geolocation satellites **88,** GPS, Galileo, Glonass, or the like as known per

se.

[0089] The system further relies on communication links, using partly wireless sections and wired sections, as known per se in the field of telecommunications.

[0090] The system further comprises a server **5.** Here the term server should be construed broadly it can be generally a server service in the cloud. As illustrated in figure 1, the system further comprises one or more mobile computing devices such as smartphones **6.** The system may further comprise a laptop, a tablet, or any suitable computing device having a display function.

[0091] Turning now to figure 2, vehicle comprises an electric machine **18** driving wheels **19.** The electric machine **18** is controlled by an inverter **17.** The inverter **17** is controlled by an onboard management unit **13.** The inverter **17** is supplied by a power network **15.** The power network is connected to the power battery **16** and is connected to the output of a DC/DC converter **7.** The converter **7** is supplied by a fuel cell **70.** The fuel cell **70** is supplied with hydrogen gas from the onboard hydrogen cartridge 2. The vehicle 1 may comprise one display device **14,** possibly controller by the management unit **13.**

[0092] The electric machine **18** can be controlled in traction mode as a motor, and sometimes the electric machine can be controlled conversely as a motor in conditions of regenerative braking.

[0093] In addition, the vehicle may comprise a refill port **12,** so that the onboard hydrogen cartridge can be refilled in situ.

[0094] In each vehicle, there is provided one or more reception area **72,** each configured to receive one onboard hydrogen cartridge. They may be provided removable fastening means to secure the hydrogen cartridge **2** in proper position within the reception area **72.**

Information System

[0095] The server **5** comprises a server application **50** configured to collect and gather data about hydrogen cartridges **2.** Both onboard and stationary hydrogen cartridges are concerned.

[0096] The server application **50** is configured to build therefrom a map of hydrogen resources across the geographical area **GZ.**

[0097] The server application **50** provides a first map content for a vehicle user, and a second map content for a fleet manager (as the one shown in figure 6). According to an option, it can be provided data filters at the client application **55,60** to choose which kind of information should be displayed or not, thereby rendering the displayed map customized to the user's need. For each hydrogen cartridge **2,** the server application **50** collects unique identifier, current geolocation, current pressure, current temperature, current filling percentage, current number of cycles, current status, and state of charge of the internal battery. The filling percentage is computed from the temperature and the pressure with the help of the expression pV = nRT.

[0098] In the cartridge status, can be included the current diagnosis status (failure or not, shocks undergone), and whether the hydrogen cartridge is aboard a vehicle or is stationary.

[0099] All this information is gathered in database **8,** either within the same server **5** or housed is in another server.

[0100] As apparent from figure 5, not only the cartridges data is collected by the server application, but also vehicle data, data about refilling station **3,** and data about H_2 production device **4,** data about stationary electric generators **100.**

[0101] Vehicle data includes a unique identifier such as the license plate number, the current geolocation, the current status, the current mileage, etc.

[0102] Data about refilling station **3** includes a unique identifier, the current geolocation, and the current status.

[0103] Data about H_2 production device **4** includes a unique identifier, the current geolocation, the current status. Other H_2 generating apparatuses are considered like Electrolysis, Vaporeforming and Pyrolysis from waste (wood, plastic, etc.) for energy recovery.

[0104] In addition, at the hydrogen relay spots **9,** there may be provided an electronic control unit **92** that can send data about at least the number of hydrogen cartridges **2** present at hydrogen relay spots **9.**

[0105] The server is also configured to handle upcoming transportation missions for people and for goods. A mission can consist in transporting a person or goods with a vehicle having a professional driver (taxi & deliveries). A mission can consist in renting a vehicle to a client who will become the driver during the mission.

[0106] The server is configured to download updated cartographic data to at least a client application **60** running on the smartphone. There may be a like/similar client application in any type of computing device. There may be a type of client application for the end user and another type of client application for a system manager and for a maintenance officer.

[0107] There is also provided a display **55** for the fleet manager or the system maintenance officer. The illustrated display **55** can be in direct or indirect connexion with the server **5.**

[0108] The display **55** shows updated cartographic data **35** comprising all current hydrogen resources available across the geographical area GZ.

[0109] The updated cartographic data includes geolocation and particulars of at least each stationary hydrogen cartridge.

[0110] One example of displayed cartographic data **35** is shown in figure 6.

[0111] Triangle marks 72 denote hydrogen relay spots **9.** Numbers on the three sides of the triangle can exhibit the total number of hydrogen cartridges present in the spot, the number of fully filled cartridges **72a,** the number of empty or nearly empty cartridges **72b,** and the number of disabled cartridges **72c.**

[0112] Pinlike marks **73** denote the positions of vehicles **1.** Square marks **71** denote electrolysis stations **4.** Round marks **74** denote refilling stations **3.**

[0113] It is to be noted that hydrogen cartridges have to be serviced on a periodic basis. There is provided inspection proceedings to check the technical characteristics of the pressurized bottle before putting it again into service.

[0114] The invention therein can also be worded as a process or method, stated as follows :

- providing a plurality of hydrogen cartridges **2,**
- providing, in vehicle(s), the reception area **72** to receive at least one onboard hydrogen cartridge, and a releasable coupling **80** to fluidly couple the pressurized bottle to the vehicle fuel cell, whereby the hydrogen cartridge forms the vehicle hydrogen supply,
- providing a plurality of hydrogen relay spots **9,** distributed across a geographical area **GZ,** each hydrogen relay spot being adapted to accommodate one more hydrogen cartridges,
- providing a server application **50** configured to collect and gather data about hydrogen cartridges,
- building therefrom a map of hydrogen resources across the geographical area **GZ,**
- downloading updated cartographic data **35** to at least a client application **60,** said updated cartographic data comprising current hydrogen resources available across the geographical area, including geolocation and particulars of each stationary hydrogen cartridge.

[0115] Regarding now the process of exchanging hydrogen cartridge in a vehicle, the sequence comprises:

x1- fluidly uncoupling the onboard hydrogen cartridge installed in the reception area,
x2- removing the onboard hydrogen cartridge from the reception area,
x3- getting access to a new hydrogen cartridge from a hydrogen relay spot,
x4- installing the new hydrogen cartridge in the reception area, thereby becoming a new onboard hydrogen cartridge,
x5- fluidly coupling the new hydrogen cartridge to the vehicle fuel cell,
x6- placing the former onboard hydrogen cartridge in one position at the hydrogen relay spot.

[0116] With this process, we provide an easy and reliable exchange/replacement of the hydrogen cartridge.

[0117] At step **x3-,** authentication is required to allow access to the new hydrogen cartridge. Thereby, only an authorized user can take a hydrogen cartridge from the hydrogen relay spot. Unauthorized persons are prevented to have access to or tempering the hydrogen cartridge.

[0118] Referring now to figure 7, a hydrogen relay spot **9** may comprise a piece of furniture with a plurality of compartments, each compartment **90** being locked by a locker **91** having unlock function. there may be provided a man-machine interface with an electronic control unit **92.**

[0119] In each vehicle **1,** the management unit **13** and the display **14** can be used to indicate to the driver a list of hydrogen relay spots within reach of the vehicle and at least the number of fully filled hydrogen cartridges available at each hydrogen relay spot of said list.

[0120] Each vehicle may make available its currently available miles autonomy to server **5,** thanks to the management unit 13 and the wireless communication means.

[0121] The server application and/or the vehicle management unit is configured to calculate a list of hydrogen relay spots within reach of the vehicle according to miles autonomy.

[0122] It is to be understood that the ecosystem promoted herein can prevail in several geographical areas **GZ** distributed across a large territory and even nationwide. Within the server, there may be a partition to distinguish each ecosystem from one another.

[0123] According to one option, the server application **50** provides a list of collect and refilling orders to a fleet staff member, said collect order prompting to collect emptied hydrogen cartridge(s) at the hydrogen relay spots **9,** and to proceed with a refilling step. This allows easy management of the ecosystem.

[0124] Further, the server application **50** may provide a list of resupply orders to a fleet staff member, said resupply order prompting to bring full hydrogen cartridge(s) to hydrogen relay spots **9.**

[0125] Further, the server application **50** may provide to a fleet staff member identification and position indication of the hydrogen cartridges to be serviced.

[0126] In addition, the server application **5** may be provided with future ordered transportation missions, known from registered users. From this, the server application calculates an anticipated map, according to the future situation. Not only the current situation is comprehensively presented to the users, but also foreseeable future situation.

[0127] Furthermore, the server application **50** could be used to build a map of other gas resources (biomethane, medical oxygen, food CO_2, etc.).

Claims

1. A system for carrying out transportation of people and/or goods based on hydrogen fuel, the system comprising a plurality of vehicles (1), each powered at least by a fuel cell (70), each vehicle comprising a hydrogen supply comprising at least one onboard hydrogen cartridge (2), the onboard hydrogen cartridge being removably mounted in a vehicle structure,

the system comprising a plurality of stationary hydrogen cartridges (2), available at a plurality of hydrogen relay spots (9), distributed across a geographical area (GZ),
wherein each of the onboard and stationary hydrogen cartridges (2) comprises a pressurized bottle and a head device including pressure and temperature sensing means, geolocating means and communication means to transmit cartridge data, at least partly wirelessly, to a remote server (5) comprised in the system,
the server (5) comprising a server application (50) configured to collect and gather data about onboard and stationary hydrogen cartridges,
wherein the server application (50) is configured to build therefrom a map of hydrogen resources across the geographical area,
wherein the server is configured to download updated cartographic data to at least a client application (60,55), said updated cartographic data comprising current hydrogen resources available across the geographical area, including geolocation and particulars of at least each stationary hydrogen cartridge.

2. The system according to claim 1, wherein all the onboard and stationary hydrogen cartridges (2) share a single mechanical interface and a single fluid interface for interoperably coupling each of them to each one of the plurality of vehicles (1).

3. The system according to any of the claims 1 to 2, wherein each hydrogen relay spot (9) is configured to accommodate one or more stationary hydrogen cartridges and the stationary hydrogen cartridges can be lockably secured in lockers (90) at the hydrogen relay spot (9).

4. The system according to any of the claims 1 to 3, wherein each hydrogen cartridge (2) comprises a generally parallelepiped protective casing (20), said protective casing encompassing the pressurized bottle and the head device therein.

5. The system according to any of the claims 1 to 4, further comprising a plurality of refilling stations (3), distributed across the geographical area (GZ), wherein the map of hydrogen resources across the geographical area also includes the geolocation and particulars of each refilling station (3).

6. The system according to any of the claims 1 to 5, further comprising a plurality of hydrogen gas producing devices (4), such as devices using electrolysis, vaporeforming, or pyrolysis, distributed across the geographical area, wherein the map of hydrogen resources across the geographical area also includes the geolocation and particulars of each H_2 production device (4).

7. The system according to any of the claims 1 to 6, wherein the fluid interface between the vehicle and the onboard hydrogen cartridge(s) includes a quick connect/disconnect coupling interface (80).

8. The system according to any of the claims 1 to 7, wherein the head device (22) comprises a battery (82), with an electrical storage capacity comprised between 3000 mAh and 9000 mAh.

9. The system according to any of the claims 1 to 8, wherein the head device (22) comprises a unique identifier for each hydrogen cartridge.

10. The system according to any of the claims 1 to 9, wherein the payload capacity of each hydrogen cartridge is comprised between 400 mg and 1 Kg of hydrogen gas, and the weight of each hydrogen cartridge is less than 30 Kilograms.

11. A **method** for implementing and operating a transportation system based on hydrogen fuel, the system comprising a plurality of vehicles (1), each powered at least by a fuel cell (70), each vehicle comprising a hydrogen supply,
the method comprising :

- providing a plurality of hydrogen cartridges (2), wherein each of the hydrogen cartridges comprises a pressurized bottle and a head device including pressure and temperature sensing means, geolocating means and communication means to transmit cartridge data remotely to a server (5),
- providing, in one or more vehicle, a reception area (72) to receive at least one onboard hydrogen cartridge, and a releasable coupling to fluidly couple the pressurized bottle to the vehicle fuel cell, whereby the hydrogen cartridge forms the vehicle hydrogen supply,
- providing a plurality of hydrogen relay spots (9), distributed across a geographical area, each hydrogen relay spot being adapted to accommodate one more hydrogen cartridges,
- providing a server application (60,55) configured to collect and gather data about hydrogen cartridges,
- building therefrom a map of hydrogen resources across the geographical area,
- downloading updated cartographic data to at least a client application, said updated cartographic data comprising current hydrogen resources available across the geographical area, including at least geolocation and particulars of each stationary hydrogen cartridge.

12. The method according to claim 11, wherein the method further comprises a sequence of cartridge exchange, said sequence comprising:

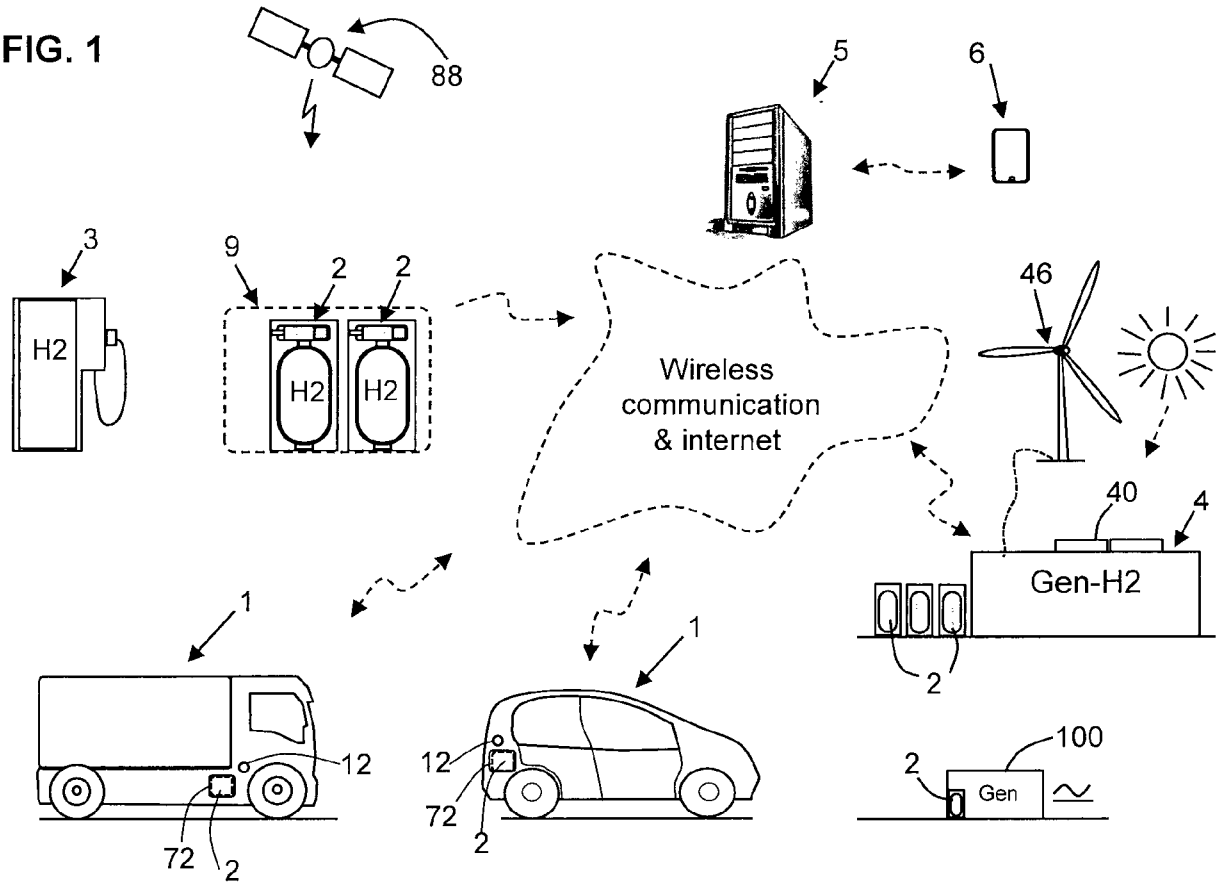
x1- fluidly uncoupling the onboard hydrogen cartridge installed in the reception area,
x2- removing the onboard hydrogen cartridge from the reception area,
x3- getting access to a new hydrogen cartridge from a hydrogen relay spot,
x4- installing the new hydrogen cartridge in the reception area, thereby becoming a new onboard hydrogen cartridge,
x5- fluidly coupling the new hydrogen cartridge to the vehicle fuel cell,
x6- placing the former onboard hydrogen cartridge in one position at the hydrogen relay spot.

13. The method according to claim 13, wherein at step **x3-,** an authentication is required to allow access to the new hydrogen cartridge.

14. The method according to claim 12, wherein the map pinpoints the geolocation and particulars of each hydrogen cartridge, and possibly each refilling station (3), and possibly each electrolysis device (4).

15. The method according to claim 12, wherein each vehicle comprises a management unit (13) and wireless communication means to make available the currently available miles autonomy to the server, and wherein the server application and/or the vehicle management unit is configured to calculate a list of hydrogen relay spots within reach of the vehicle and at least the number of fully filled hydrogen cartridges available at each hydrogen relay spot of said list.

FIG. 1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H2
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communication
& internet
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12
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100
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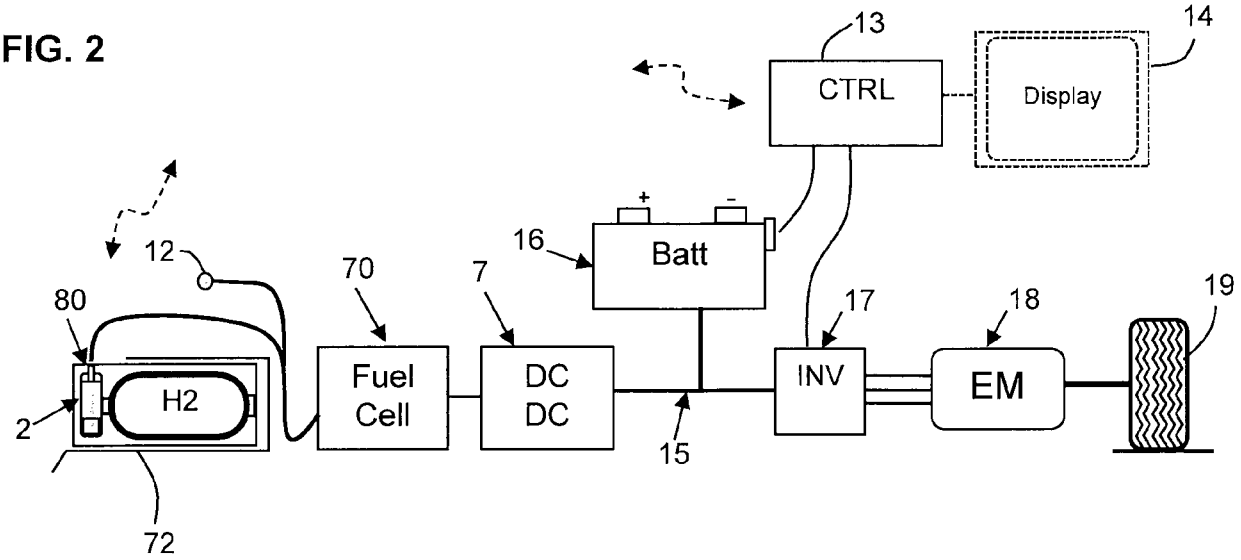
FIG. 2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-
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DC
INV
EM
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15
72

FIG. 3

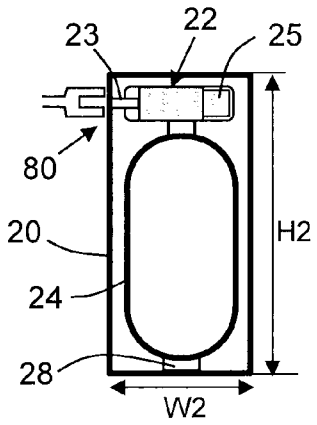


FIG. 4

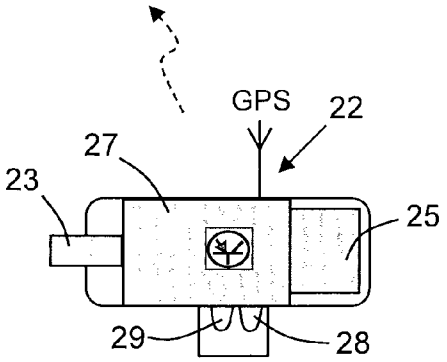


FIG. 5

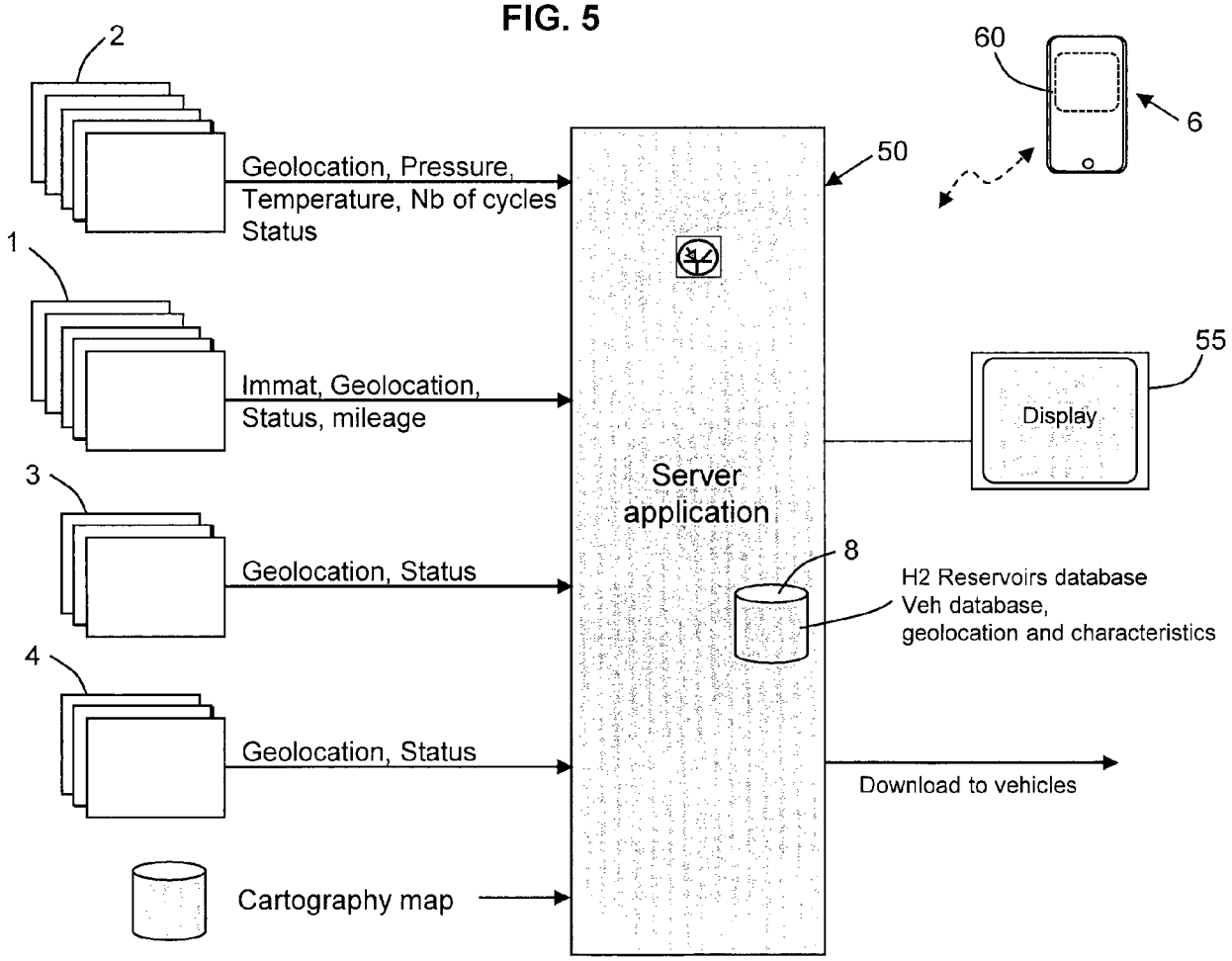
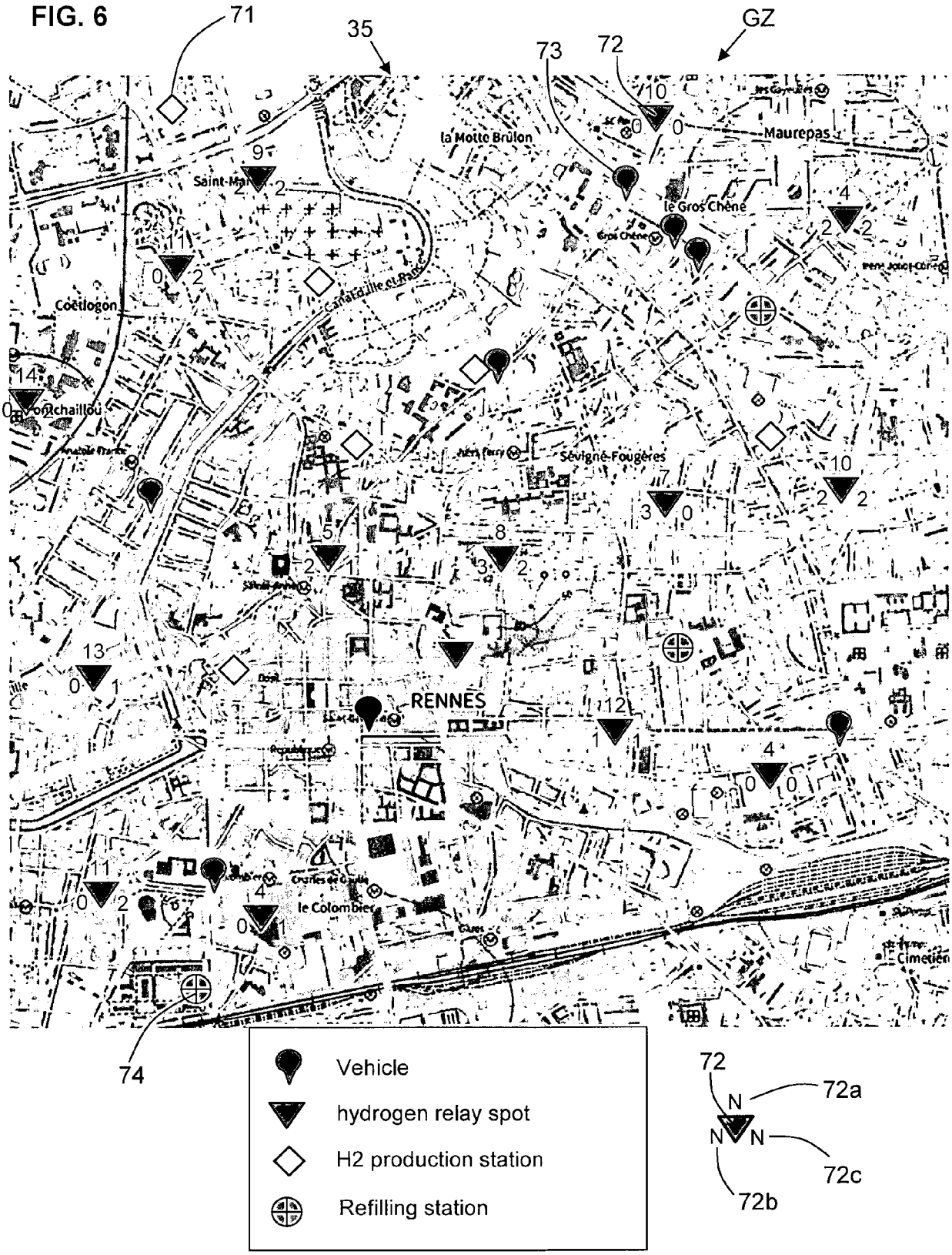


FIG. 6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35
73
72
GZ
la Motte Brûlon
Maurepas
le Gros Chêne
Saint-Martin
Cœtlogon
Sévigné-Fougères
RENNES
le Colombier
74
Vehicle
hydrogen relay spot
H2 production station
Refilling station
72
72a
72b
72c
N

FIG. 7

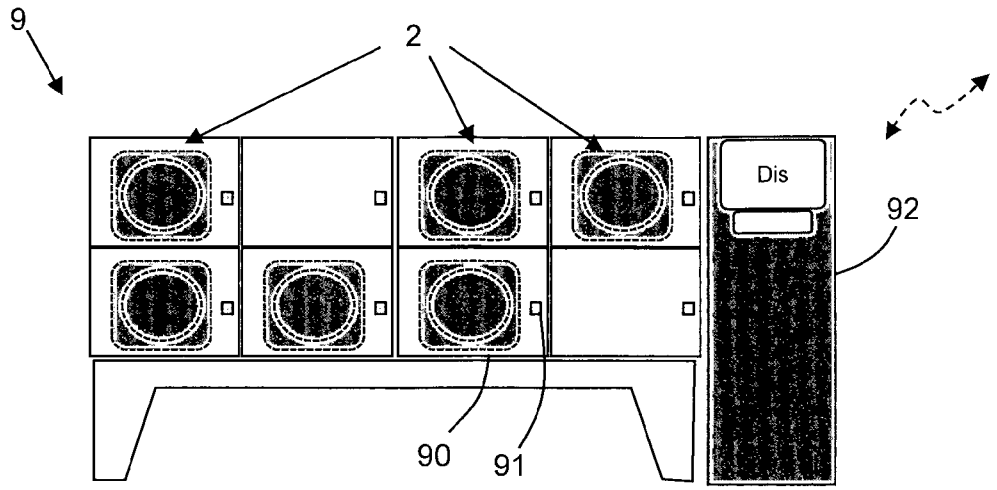
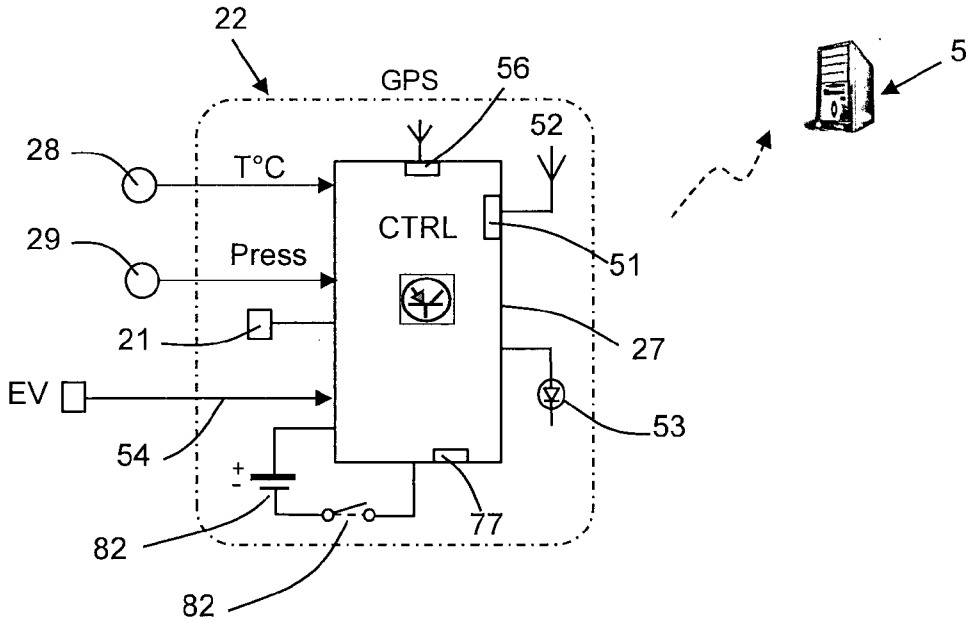

9
2
Dis
92
90
91

FIG. 8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EUROPEAN SEARCH REPORT

Application Number
EP 23 31 5349

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F17C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 February 2024	Fritzen, Claas

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19-02-2024

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