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(54) UNMANNED UNDERWATER VEHICLE FUEL CELL POWERED CHARGING SYSTEM AND METHOD

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H01M 10/44 (2006.01)
G21B 29/12 (2006.01)

(52) **U.S. Cl.** **320/101**; 166/338

(58) **Field of Classification Search** 320/101; 114/312; 166/338; 429/17
See application file for complete search history.

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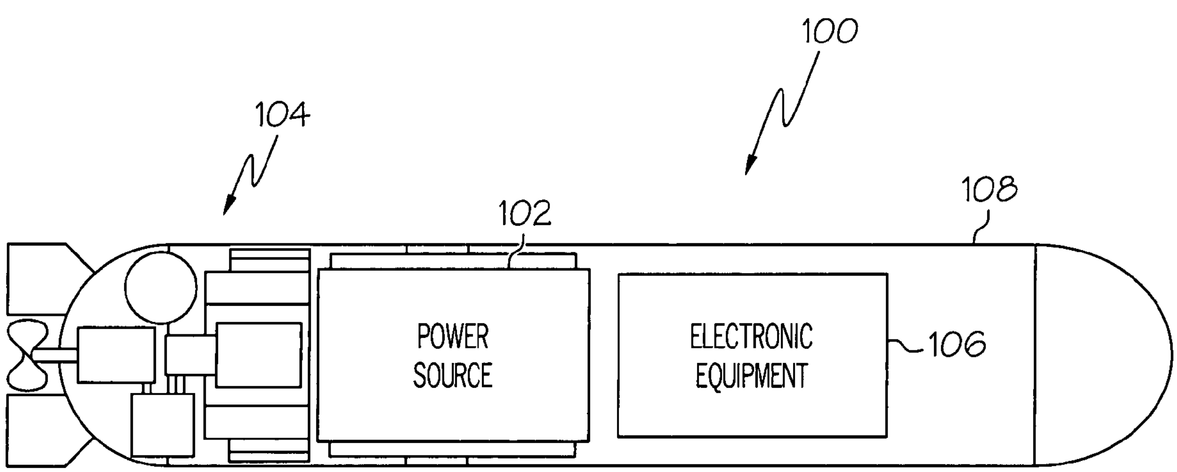
(57) **ABSTRACT**

A charging system for an unmanned underwater vehicle (UUV) is disposed within a submerged docking station. The charging system includes a battery, a fuel cell, a fuel source, and a charge controller. The battery supplies electrical power to an electrical distribution bus in the docking station. The charge controller monitors the charge state of the battery and, when needed, activates the fuel cell to recharge the battery. The charge controller also activates the fuel cell when a UUV is docked in the docking station for recharging of its power plant.

24 Claims, 3 Drawing Sheets



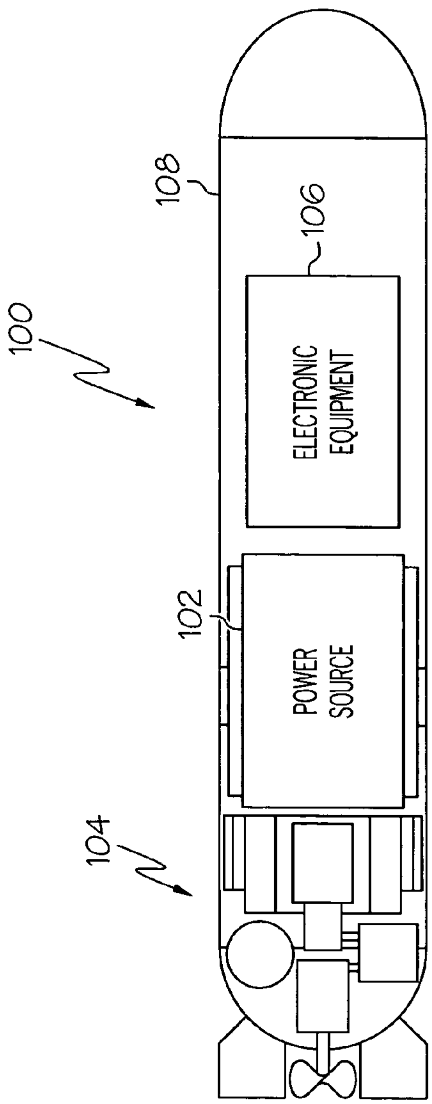

100
108
106
ELECTRONIC EQUIPMENT
102
POWER SOURCE
104

FIG. 1

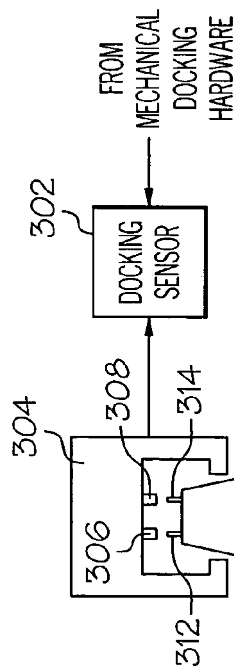
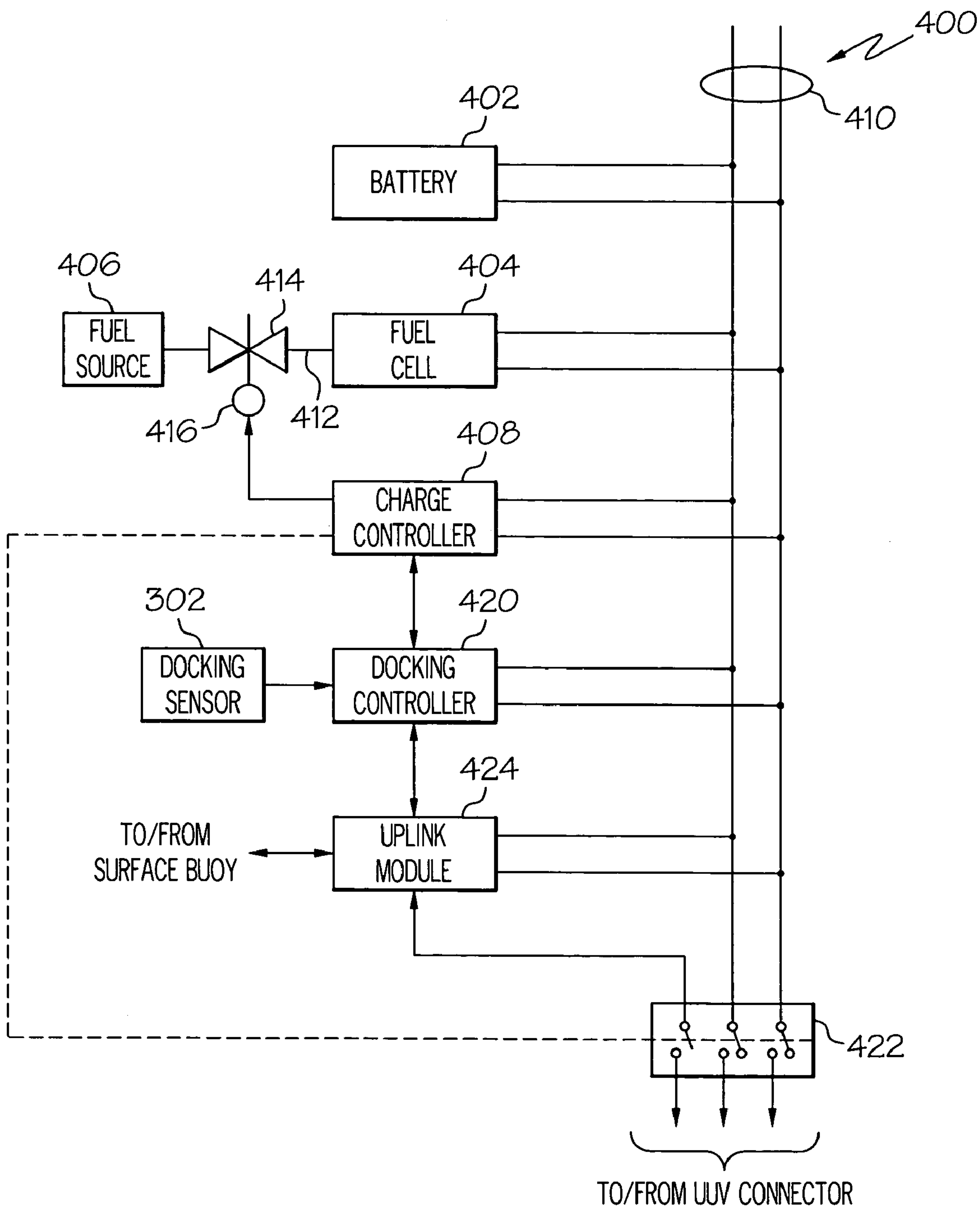

FROM MECHANICAL DOCKING HARDWARE
302
DOCKING SENSOR
304
308
314
310
306
312

FIG. 3



400
410
402
BATTERY
406
FUEL SOURCE
414
404
FUEL CELL
416
412
408
CHARGE CONTROLLER
302
DOCKING SENSOR
420
DOCKING CONTROLLER
424
TO/FROM SURFACE BUOY
UPLINK MODULE
422
TO/FROM UUV CONNECTOR

FIG. 4

UNMANNED UNDERWATER VEHICLE FUEL CELL POWERED CHARGING SYSTEM AND METHOD

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/529,337, filed Dec. 11, 2003.

FIELD OF THE INVENTION

The present invention relates to unmanned underwater vehicles and, more particularly, to a fuel cell powered charging system and method that may be used to replenish a power source in an unmanned underwater vehicle (UUV) while the UUV remains submerged.

BACKGROUND OF THE INVENTION

Unmanned underwater vehicles (UUVs) may be used to conduct various military and non-military operations. Such operations may include, for example, maritime reconnaissance, undersea searching, undersea surveying, submarine tracking and trailing, monitoring of various types of sea traffic, monitoring animal and plant life, and communication and/or navigational aids. These and other operational capabilities make UUVs a potential option in providing a seagoing component for homeland security. In a homeland security scenario, multiple UUVs could be deployed along the coasts of the country, and conduct various security-related monitoring and surveillance operations.

For most military and homeland security operations, it may be desirable that the UUVs remain submerged for relatively long periods of time. As such, many UUVs may include a power plant that is powered by a power source that can generate a desired level of power while the UUV remains submerged, while at the same time generating a relatively low level of acoustic noise. Various types of power sources have been used and/or developed that meet one or more of these objectives. Some examples include batteries, and rechargeable heat sources. Although batteries and rechargeable heat sources may be advantageous from a cost standpoint, both of these types of power sources may need periodic recharging.

In addition to the need to be periodically recharged or refueled, at some point during UUV operation, it may be desirable to retrieve various types of data from, and to supply various types of data to, the UUV. Such data can include stored intelligence data, data associated with equipment on-board the UUV, and data that updates UUV mission programming.

In many current UUVs, the need to periodically recharge, and/or retrieve data from, and/or supply data to, the UUV may require that the UUV be periodically retrieved, and taken out of service. In many instances, this results in the UUV being surfaced, and removed from the water, in order to conduct these operations. Moreover, some current UUVs may be periodically taken out of service to inspect on-board equipment to determine if maintenance should be conducted. In both instances, this can be a costly and time-consuming operation, and can reduce overall mission effectiveness.

Hence, there is a need for a system and method that will recharge a UUV, and/or retrieve data from, and/or supply data to, a UUV without having to surface the UUV and remove it from the water. The present invention addresses one or more of these needs.

SUMMARY OF THE INVENTION

The present invention provides a system and method for recharging a UUV, without having to surface the UUV and remove it from the water. The system and method also enable retrieving data from, and/or supplying data to, a UUV without having to surface the UUV and remove it from the water.

In one embodiment, and by way of example only, a charging system for an unmanned underwater vehicle includes an electrical port, a battery, a fuel source, a fuel cell, and a controller. The electrical port is adapted to electrically couple to an unmanned underwater vehicle (UUV). The fuel cell is adapted to selectively receive fuel from the fuel source and is configured, upon receipt thereof, to generate electrical power. The controller is adapted to receive a UUV docking signal that indicates at least when the electrical port is electrically coupled to at least a portion of the UUV and is operable, in response thereto, to selectively fluidly couple the fuel cell hydrogen inlet to the fuel source and selectively electrically couple the fuel cell to the electrical port.

In yet another exemplary embodiment, a docking station for an unmanned underwater vehicle (UUV) includes a housing, a UUV docking port, an electrical port, a fuel source, a fuel cell, and a charge controller. The UUV docking port is disposed within the housing and is configured to dock a UUV therein. The electrical port is disposed at least partially within the UUV docking port, and is adapted to electrically couple to a docked UUV. The fuel source is coupled to the housing. The fuel cell is disposed within the housing, is adapted to selectively receive fuel from the fuel source is configured, upon receipt thereof, to generate electrical power. The charge controller is adapted to receive a UUV docking signal that indicates at least when the electrical port is electrically coupled to the docked UUV, and is operable, in response thereto, to selectively fluidly couple the fuel cell to the fuel source and to selectively electrically couple the fuel cell to the electrical port.

In yet another exemplary embodiment, a method of charging a power source for an unmanned underwater vehicle (UUV) includes electrically coupling an electrical port to the at least a portion of the UUV power source. Fuel is supplied to a fuel cell that is configured to generate electrical power upon receipt of the fuel. The fuel cell is electrically coupled to the electrical port, to thereby charge the UUV power source using at least the fuel cell.

Other independent features and advantages of the preferred UUV charging system and method will become apparent from the following detailed description, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified functional block diagram representation of an exemplary unmanned underwater vehicle (UUV);

FIG. **2** is a simplified perspective view of an exemplary UUV docking station that may be used to dock one or more UUVs, such as the exemplary UUV shown in FIG. **1**;

FIG. **3** is a simplified schematic representation illustrating exemplary mechanical and electrical interconnections between the UUV docking station and a UUV; and

FIG. **4** is a functional block diagram of an exemplary charging system that may be used to recharge a UUV while docked in the UUV docking station of FIG. **1**.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

The following detailed description of the invention is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background of the invention or the following detailed description of the invention.

An exemplary embodiment of an unmanned underwater vehicle (UUV) **100** is shown in FIG. **1**, and includes a power source **102**, a power plant **104**, and on-board electronic equipment **106**, all housed within a hull **108**. The power source **102** is a rechargeable power source and is used to supply power to the power plant **104**. The power source **102** may be any one of numerous types of rechargeable power sources such as, for example, a rechargeable heat source for driving a closed Brayton cycle (CBC), and/or a battery. If a rechargeable heat source is used, it may be any one of numerous types of rechargeable heat sources such as, for example, a porous solid or a molten salt. Similarly, if a battery is used, it may be any one of numerous types of rechargeable batteries such as, for example, a lead-acid battery, a nickel-cadmium battery, or a lithium battery.

The power plant **104** uses the power supplied from the power source **102** to generate propulsion power and electrical power for the UUV **100**. Thus, the power plant **104** preferably includes one or more turbines, generators, and/or motors to supply the needed propulsion and electrical power. It will be appreciated that the particular number, type, and configuration of equipment and components used to implement the power plant **104** may vary depending on the specific power source **102** that is used.

The on-board electronic equipment **106** may also vary, depending on the purpose and mission of the UUV **100**, the configuration of the power source **102**, and/or the configuration of the power plant **104**. No matter the particular type of electronic equipment **106** that is used, or its particular configuration, the on-board electronic equipment **106** is preferably configured to gather and store data regarding various equipment and systems on-board the UUV **100**, including the power source **102** and power plant **104**, as well as data associated with the mission of the UUV **100**. The on-board electronic equipment **106** is also preferably configured to transmit some or all of the data it gathers and stores to, and/or to receive various types of data from, a remote station (not illustrated).

The UUV power source **102** can be recharged, and data can be transferred to/from the on-board electronic equipment **106**, whenever the UUV **100** is docked in a docking station. An exemplary embodiment of a docking station **200** is illustrated in FIG. **2**, and includes a housing **202**, one or more buoyancy tanks **204**, and one or more docking ports **206**. When deployed, the docking station **200** is preferably submerged below the surface **208** of the body of water **210** in which it is placed, and is tethered to a surface buoy **212** via a tether line **214**. The tether line **214** may be any one of numerous types of tether lines **214** that preferably include one or more sets of conductors for transmitting data between the surface buoy **212** and the docking station **200**, and may additionally include one or more conduits for supplying fuel and/or air to the docking station **200**. The position of the surface buoy **212** is maintained using an anchor **216** that is coupled to the surface buoy **212** via an anchor line **218**. An additional length of anchor line **220** may also be coupled between the docking station **200** and the surface buoy anchor line **218**.

The surface buoy **212** may be an existing surface buoy **212** or may be specifically designed to interface with the docking station **200**. In either case, the surface buoy **212** preferably includes one or more antennae **222** for transmitting data to and receiving data from the previously-mentioned remote station. The surface buoy **212** also preferably includes one or more transceivers **224** configured to transmit data to and receive data from the non-illustrated remote station. The transceivers **224**, or separate transceivers, are also preferably configured to transmit data to and receive data from the on-board electronic equipment **106** in a docked UUV **100**. It will be appreciated that the surface buoy **212** also preferably includes one or more fuel and/or air connections, which are used to service the submerged docking station **200**.

The buoyancy tank **204** is coupled to the docking station housing **202** and, in the depicted embodiment, is disposed external to the housing **202**. It will be appreciated that the docking station **200** could include more than one buoyancy tank **204**, and that the one or more buoyancy tanks **204** could be disposed either within or external to the housing **202**. Moreover, as will be described in more detail further below, the buoyancy tank **204** in the depicted embodiment also functions as a storage tank for fuel that is used by one or more fuel cells housed within the docking station housing **202**.

The docking ports **206** are disposed within the docking station housing **202** and are each configured to receive, and dock, a single UUV **100** therein. In the depicted embodiment, the housing **202** is configured to include two docking ports **206**; however, it will be appreciated that this is merely exemplary, and that the housing **202** could be configured to include more or less than this number of docking ports **206**. Moreover, although the docking ports **206** are shown as being configured to receive and dock a single UUV **100** therein, it will be appreciated that one or more of the docking ports **206** could be configured to receive and dock more than one UUV **100**.

No matter the particular number of docking ports **206**, or the particular number of UUVs **100** each docking port **206** can receive and dock, it will be appreciated that each docking port **206** includes hardware sufficient to mechanically capture a UUV **100**, and to electrically couple to portions of the UUV **100**. A simplified representation of a portion of this hardware is shown in FIG. **3**, and includes a docking sensor **302**, and a docking connector **304**. The docking sensor **302** is configured to sense when the UUV **100** is properly docked in the docking port **206** and is ready to be recharged. As will be described more fully below, the docking sensor **302** supplies an appropriate sensor signal to equipment within the docking station **200** indicating that the UUV **100** is properly docked, both mechanically and electrically.

The docking connector **304** includes a data port **306** and a power port **308**. When the UUV **100** is properly docked within a docking port **206**, the docking connector **304** is couple to a UUV connector **310**, which also includes a data port **312** and a power port **314**. The docking connector data port **306** and UUV connector data port **312** are configured to electrically couple together, as are the docking connector power port **308** and the UUV connector power port **314**. The data connector ports **306**, **312** are used to transmit data from, and/or supply data to, the on-board electronic equipment **106**, and the power ports **308**, **314** are used to supply electrical power to recharge the power source **102**. It will be appreciated that if the power source **102** is a rechargeable heat source, the electrical power is supplied to one or more induction heater coils (not illustrated) to reheat (e.g., recharge) the heat source. The electrical power that is used to recharge the UUV power source **102** is supplied from a charging system that preferably forms part of the docking station **200**. A functional block diagram of the charging system is shown in FIG. **4**, and will now be described.

The charging system **400** includes a battery **402**, a fuel cell **404**, a fuel source **406**, and a charge controller **408**. The battery **402** may be sized, and include a desired number of cells, to supply a desired voltage and current magnitude, and may be implemented as any one of numerous types of rechargeable batteries such as, for example, the battery types previously mentioned. The battery **402** is coupled to a power distribution bus **410**, which is used to distribute electrical power to the charge controller **408** and various other electrical and electronic equipment on or within the docking station **200**. As will be described more fully below, the battery **402** supplies electrical power to the power distribution bus **410** whenever the fuel cell **404** is not being used to supply electrical power.

The fuel cell **404** is electrically coupled to the power distribution bus **410**, and is used to generate electrical power to both recharge the docking station battery **402**, and to recharge the UUV power source **102**. A fuel cell **404**, as is generally known, is an electrochemical energy conversion device that converts fuel into electricity by catalytically reacting fuel that is supplied to the fuel cell **404** to create an electric current. Depending on the fuel and particular type of fuel cell used, different chemical reactions will occur, and differing types of byproducts, such as water and/or carbon dioxide, are created. It will be appreciated that the fuel cell **404** may be implemented as any one or more of numerous types fuel cells including, for example, a PEMFC (polymer electrolyte membrane fuel cell), a PAFC (phosphoric acid fuel cell), a DMFC (direct methanol fuel cell), an AFC (alkaline fuel cell), a MCFC (molten carbonate fuel cell), an SOFC (solid oxide fuel cell), or a PEFC (proton exchange fuel cell). It will additionally be appreciated that the type of fuel may vary, depending at least in part on the type of fuel cell **404** used.

No matter the particular type of fuel cell **404** or fuel that is used, the fuel is stored in, and supplied from, the fuel source **406**. In the depicted embodiment, the fuel source **406** also functions as the buoyancy tank **204**, though it will be appreciated that it could be a different tank. A fuel supply line **412** is disposed between the fuel source **406** and the fuel cell **404**. A fuel supply valve **414** is mounted on the fuel supply line **412** and, depending on its position, controls the flow of fuel from the fuel source **406** to the fuel cell **404**. In particular, when the fuel supply valve **414** is closed, fuel does not flow to the fuel cell **404**. Conversely, when the fuel supply valve **414** is open, fuel flows from the fuel source **406** to the fuel cell **404**. The fuel supply valve **414** is moved between the open and closed positions via a valve actuator **416**. The valve actuator **416** is responsive to valve position command signals it receives from the charge controller **408**, which will now be described.

The charge controller **408** controls the overall operation of the charging system **400**. In the depicted embodiment, the charge controller **408** controls the charging system **400** to operate in two separate modes, depending upon whether a UUV **100** is, or is not, docked and charging. In the first mode, referred to herein as the "dormant mode," the charging system **400** is not used to charge a UUV **100**. In the dormant mode, the battery **402** is used to supply electrical power to the power distribution bus **410**. The charge controller **408** monitors the state of charge of the battery **402**, and when it drops to a predetermined charge state, the charge controller **408** initiates a recharge of the battery **402**. In the depicted embodiment, the charge controller **408** is electrically coupled to the power distribution bus **410**, and monitors battery charge state by monitoring battery voltage, on the basis of power distribution bus voltage. It will be appreciated, however, that the charge controller **408** could monitor and determine battery charge state in any one of numerous other ways.

To initiate a recharge of the battery **402**, the charge controller **408** supplies an appropriate valve position command signal to the valve actuator **416**. In turn, the valve actuator **416** moves the fuel supply valve **414** to the open position, which allows fuel to flow from the fuel source **406** to the fuel cell **404**, via the fuel supply line **412**. The fuel cell **404** is in turn activated, and begins generating electrical power. This electrical power is used to recharge the battery **402**, via the power distribution bus **410**. When the battery **402** is recharged, the charge controller **408** then supplies an appropriate valve position command to the valve actuator **416**, which moves the fuel supply valve **414** to the closed position and deactivates the fuel cell **404**. The battery **402** then resumes its function of supplying electrical power to the power distribution bus **410**.

The second mode that the charge controller **408** operates in is referred to herein as the "docking mode." In the docking mode, the charging system **400** is used to charge/recharge a UUV **100**, via the docking connector **304**. More specifically, the docking connector power port **308** receives electrical power from the power distribution bus **410**, via a charge control switch **422** that is electrically coupled between the power distribution bus **410** and the docking connector power port **308**. The position of the charge control switch **422**, similar to that of the fuel supply valve **414**, is controlled by the charge controller **408**.

To initiate a recharge of a UUV **100**, the UUV **100** is first properly docked in one of the docking ports **206**. When the UUV **100** is properly docked, and the docking connector **304** is coupled to the UUV connector **310**, the docking sensor **302**, as was noted above, issues an appropriate signal. In the depicted embodiment, this signal is supplied to a docking controller **420**, which in turn supplies a signal to the charge controller **408**. It will be appreciated, however, that the functions of the docking controller **420** could be implemented in the charge controller **408**, and vice-versa. In any case, the charge controller **408**, upon receiving the signal indicating that the UUV **100** is properly docked, supplies an appropriate valve position command signal to the actuator **416**, which causes the fuel supply valve **414** to open and the fuel cell **404** to begin generating electrical power. The charge controller **408** also supplies an appropriate switch position command signal to the charge control switch **422**, which causes the charge control switch to shut and electrically couple the power distribution bus **410** to the docking connector power port **308**. As a result, the electrical power generated by the fuel cell **404** is supplied to the UUV **100**, to recharge the UUV power source **102**.

The fuel cell **404** remains activated at least until the UUV power source **102** is recharged, the UUV **100** is released from the docking port **206**, and the battery **402** is fully charged. Once this occurs, the charge controller **408** supplies an appropriate valve position command signal to the valve actuator **416**, and an appropriate switch position control signal to the charge control switch **422**. In response to these signals, the valve actuator **416** moves the fuel supply valve **414** to the closed position, and the charge control switch **422** is moved to its open position. As a result, the fuel cell **404** is deactivated, and the power distribution bus **410** is electrically decoupled from the docking connector power port **308**. It will be appreciated that in some instances, the UUV **100** may be released from the docking port **206** before the battery **402** is fully charged. In such an instance, the charge control switch **422** may be moved to the open position before the fuel cell **404** is deactivated.

It was previously noted that the UUV power source **102** could be any one of numerous types of rechargeable power sources. It will be appreciated that the manner in which the charging system **400** recharges the UUV power source **102** may differ for differing types of rechargeable power sources **102**. Thus, the charge controller **408** may additionally receive a signal representative of the type of power source **102** that is going to be recharged. This signal may be supplied directly to the charge controller **408**, or may be supplied to the charge controller **408** via the docking controller **420**.

As FIG. **4** additionally shows, an electronic uplink module **424** may also be included in the docking station **200**. The uplink module **424** is used to retrieve data from, and transfer data to, the UUV **100**, via the docking and UUV data connector ports **306**, **312**, and transfer the retrieved data to the one or more transceivers **224** in the surface buoy **212**, or to directly transmit the data to a remote station via the antenna **222**. When the uplink module **424** is included, the charging system **400** is preferably operated in the docking mode until the UUV power source **102** is recharged, the UUV **100** is released from the docking port **206**, the uplink module **424** completes its data transfers to and/or from the UUV **100**, and the battery **402** is fully charged.

It will be appreciated that the charging system **400** is described herein as being installed in the docking station **200**. It will be appreciated, however, that in an alternative embodiment the charging system **400** is installed in the surface buoy **212**. In this embodiment, the electrical power the charging system **400** generates is supplied to the UUV **100** via the tether line **214**.

While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt to a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

We claim:

1. A charging system for an unmanned underwater vehicle, comprising:

an electrical port adapted to electrically couple to an unmanned underwater vehicle (UUV);

a fuel source;

a fuel cell adapted to selectively receive fuel from the fuel source and configured, upon receipt thereof, to generate electrical power;

a battery; and

a controller adapted to receive a UUV docking signal that indicates at least when the electrical port is electrically coupled to at least a portion of the UUV and one or more signals representative of at least a state of charge of the battery, the controller operable, in response to the UUV docking signal, to (i) selectively fluidly couple the fuel cell to the fuel source and (ii) selectively electrically couple the fuel cell to the electrical port, and further operable, in response to the one or more signals representative of at least a state of charge of the battery, to selectively electrically couple the fuel cell to the battery, to thereby recharge the battery to a predetermined state of charge.

2. The system of claim **1**, further comprising:

a data transfer module adapted to receive data from the UUV and transfer the received data to data receptor.

3. The system of claim **1**, wherein the data transfer module is electrically coupled to receive power from either, or both, the battery or fuel cell.

4. The system of claim **1**, further comprising:

a UUV docking control module adapted to receive a signal representative of the docking status of the UUV and operable, in response thereto, to supply the UUV docking signal.

5. The system of claim **4**, wherein the UUV docking control module is electrically coupled to receive power from either, or both, the battery or fuel cell.

6. The system of claim **1**, wherein the fuel source comprises:

a tank; and

one of hydrogen and a hydrocarbon stored therein.

7. The system of claim **1**, wherein the controller is further operable, in response to the UUV docking signal, to supply one or more valve position command signals, and wherein the system further comprises:

a conduit disposed between the fuel source and the fuel cell;

a valve mounted on the conduit and moveable between a closed position, in which the fuel source is not in fluid communication with the fuel cell, and an open position, in which the fuel source is in fluid communication with the fuel cell; and

a valve actuator coupled to receive the valve position command signals from the controller, and further coupled to the valve, the valve actuator responsive to the valve position command signals to move the valve between the closed and open positions.

8. The charging system of claim **1**, wherein the controller is further operable, in response to the UUV docking signal, to supply one or more switch command signals, and wherein the system further comprises:

a switch coupled between the electrical pot and the fuel cell and moveable between an open position, in which the fuel cell is not electrically coupled to the electrical port, and a closed position, in which the fuel cell is electrically coupled to the electrical port,

wherein the switch is further coupled to receive the switch command signals and is operable, in response thereto, to selectively move between the open and closed positions.

9. The charging system of claim **1**, wherein the controller is further coupled to receive a signal that indicates a type of rechargeable power source that is on-board the UUV and is further operable, in response thereto, control a recharge operation of the rechargeable power source based at least in part on the power source type.

10. A docking station for an unmanned underwater vehicle (UUV), comprising:

a housing;

a UUV docking port disposed within the housing and configured to dock a UUV therein;

an electrical port disposed at least partially within the UUV docking port, the electrical port adapted to electrically couple to a docked UUV;

a fuel source coupled to the housing;

a fuel cell disposed within the housing, the fuel cell adapted to selectively receive fuel from the fuel source and configured, upon receipt thereof, to generate electrical power;

a battery; and

a charge controller adapted to receive a UUV docking signal that indicates at least when the electrical port is electrically coupled to the docked UUV and one or more signals representative of at least a state of charge of the battery, the charge controller operable, in response to the UUV docking signal, to (i) selectively fluidly couple the fuel cell to the fuel source and (ii) selectively electrically couple the fuel cell to the electrical port, and further operable, in response to the one or more signals representative of at least a state of charge of the battery, to selectively electrically couple the fuel cell to the battery, to thereby recharge the battery to a predetermined state of charge.

11. The UUV docking station of claim **10**, further comprising:

a sensor adapted to sense at least when a UUV is properly docked in the UUV docking port, and configured to supply a sensor signal representative thereof;

a UUV docking controller coupled to receive the signal from the sensor and operable, in response thereto, to supply the UUV docking signal to the charge controller.

12. The UUV docking station of claim **10**, further comprising:

a sensor adapted to sense at least when a UUV is properly docked in the UUV docking port, and configured to supply a sensor signal representative thereof to the charge controller,

wherein the sensor signal is the UUV docking signal.

13. The UUV docking station of claim **10**, further comprising:

a data transfer module adapted to receive data from the UUV and transfer the received data to data receptor.

14. The UUV docking station of claim **13**, wherein the data transfer module is electrically coupled to receive power from either, or both, the battery or fuel cell.

15. The UUV docking station of claim **10**, further comprising:

a UUV docking control module adapted to receive a signal representative of the docking status of the UUV and operable, in response thereto, to supply the UUV docking signal.

16. The UUV docking station of claim **15**, wherein the UUV docking control module is electrically coupled to receive power from either, or both, the battery or fuel cell.

17. The UUV docking station of claim **10**, wherein the fuel source comprises:

a tank; and

one of hydrogen and a hydrocarbon stored therein.

18. The UUV docking station of claim **10**, wherein the charge controller is further operable, in response to the UUV docking signal, to supply one or more valve position command signals, and wherein the system further comprises:

a conduit disposed between the fuel source and the fuel cell;

a valve mounted on the conduit and moveable between a closed position, in which the fuel source is not in fluid communication with the fuel cell, and an open position, in which the fuel source is in fluid communication with the fuel cell; and

a valve actuator coupled to receive the valve position command signals from the charge controller, and further coupled to the valve, the valve actuator responsive to the valve position command signals to move the valve between the closed and open positions.

19. The UUV docking station of claim **10**, the charge controller is further operable, in response to the UUV docking signal, to supply one or more switch command signals, and wherein the system further comprises:

a switch coupled at least between the electrical port and the fuel cell and moveable between an open position, in which the fuel cell is not electrically coupled to the electrical port, and a closed position, in which the fuel cell is electrically coupled to the electrical port,

wherein the switch is further coupled to receive the switch command signals and is operable, in response thereto, to selectively move between the open and closed positions.

20. The UUV docking station of claim **10**, wherein the charge controller is further coupled to receive a signal that indicates a type of rechargeable power source that is onboard the UV and is further operable, in response thereto, control a recharge operation of the rechargeable power source based at least in part on the power source type.

21. A method of charging a power source in an unmanned underwater vehicle (UUV), comprising the steps of:

electrically coupling an electrical port to at least a portion of the UUV power source;

supplying fuel to a fuel cell that is configured to generate electrical power upon receipt of the fuel; and

electrically coupling the fuel cell to the electrical port, to thereby charge the UUV power source using at least the fuel cell;

determining a state of charge of a battery; and

based at least in part on the determined state of charge, selectively supplying the fuel to the fuel cell and selectively electrically coupling the fuel cell to the battery, to thereby recharge the battery to a predetermined state of charge.

22. The method of claim **21**, further comprising:

determining a docking status of the UUV.

23. The method of claim **21**, further comprising:

transferring data from the UUV while charging the UUV power source.

24. The method of claim **21**, wherein the UUV power source is one of a plurality of types of power sources, and wherein the method further comprises:

determining the type of rechargeable power source; and

charging the UUV power source based at least in part on its type.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

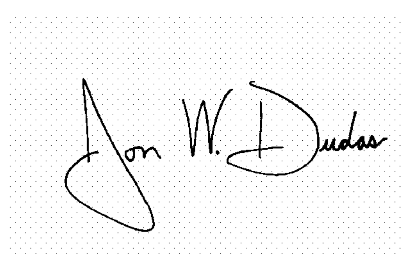
PATENT NO. : 7,183,742 B2
APPLICATION NO. : 10/813704
DATED : February 27, 2007
INVENTOR(S) : Calvin C. Potter et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 8, line 47, “pot” should be changed to --port--.
Column 10, line 29, “UV” should be changed to --UUV--.

Signed and Sealed this

Fifth Day of June, 2007



JON W. DUDAS
Director of the United States Patent and Trademark Office

13. The vehicle of claim 12 further characterized in that the contrasting visible areas are provided by features of the work environment not specially positioned to define the vehicle path of movement.

14. The vehicle of claim 13 further characterized in that the contrasting visible areas are formed by ceiling lights.

15. The combination of claim 11 further comprising a light mounted on the vehicle to illuminate the surroundings generally above the vehicle so that the defined features in those surroundings may be observed by the video camera even though the vehicle may be operating in an otherwise darkened area.

16. The vehicle of claim 10 further characterized in that the means for recording include means enabling the operator to select successive sets of two or more fixed contrasting visible areas as the vehicle is moved by the operator along the predetermined path.

17. The vehicle of claim 16 further characterized in that geometric points derived from the same successive sets of two or more fixed contrasting visible areas are used to determine the actual position and angular orientation of the vehicle during operation without an operator and form the basis for vehicle course corrections.

18. The combination comprising a vehicle intended primarily for unmanned operation, having a frame supported on wheels, drive means for propelling the vehicle and steering means for steering it,

means for operating said vehicle in a manual teaching mode in an area unmodified for the specific use of guiding an unmanned vehicle and along a desired course that an operator of the vehicle wants it to follow in a subsequent unmanned mode,

a generally vertically directed video camera mounted on the vehicle, image processing means connected to the video camera, computer means including a memory connected to the image processing means,

means for successively selecting sets of two or more defined features in the surroundings generally above the vehicle in the field of view of the video camera as the vehicle is operated along the desired course in the teaching mode, observing such features with the video camera, obtaining successive representations of the locations of geometric points derived from the features in the sets of two or more features from the observations so as to obtain simultaneously both the X and Y axis coordinates of geometric points derived from the said defined features analogous to the desired path, and electronically recording these successive representations in the computer memory,

means for positioning the vehicle close to or at the start of the same desired course after the teaching mode is complete and starting the vehicle in unmanned operation with the video camera again observing the same sets of two or more features generally above the vehicle,

means for obtaining successive representations of the locations of the same geometric points derived from the same features in the same sets of two or more features as were observed while operating in the teaching mode and comparing such representations with the location representations recorded while operating in the teaching mode to simultaneously provide lateral error on the X axis, position on the Y axis and angular orientation error,

means for deriving course corrective signals from the comparisons and means to apply the course corrective signals for the X-axis error and angular orientation error to the steering means of the vehicle so as to maintain the unmanned vehicle on a course essentially the same as the course which was traveled during the teaching mode.

19. A guidance system for a primarily automated vehicle which operates on a generally horizontal surface wherein a video camera mounted on the vehicle is used to successively observe certain overhead contrasting randomly positioned features generally above the vehicle and wherein the camera images of those features are processed into digital representations of the (x,y) coordinates in a horizontal plane of geometric points derived from the features, and wherein a set of such representations obtained during a teaching mode trip along a desired route is stored in a data base and wherein another set of similarly obtained and processed representations of the (x,y) coordinates in a horizontal plane of geometric points derived from the same overhead features obtained during a subsequent automated trip along the same route is compared against the set which was stored in the data base, and wherein the comparison is processed to provide course error signals between the course followed during the teaching mode trip and the course followed during the automated trip, and wherein the course error signals are processed to provide course corrective signals to direct the steering of the vehicle to cause it to follow essentially the same route during the automated trip as was traveled during the teaching mode trip.

20. The guidance system of claim 19 wherein the video camera is mounted with the center axis of its optical system essentially perpendicular to the surface on which the vehicle operates so that the (x) and (y) coordinate information that may be derived from the observed overhead features will apply to a plane essentially parallel to the surface on which the vehicle operates.

21. The guidance system of claim 19 further characterized in that during the teaching mode the vehicle repeatedly measures the height above the video camera of each of the observed overhead features and stores the measurements in the data base.

22. A method for guiding a vehicle through a desired path in a building having an existing overhead with a discernible pattern made up of various elements generally arranged in a horizontal plane, including the steps of manually guiding the vehicle through the desired path in a first pass, recording the locations of geometric points derived from the various elements of the pattern from the vehicle from time to time while the vehicle is being so moved to establish an X and Y axis recording analogous to the desired path, thereafter causing the vehicle to move unattended through the desired path in the building, observing the locations of geometric points derived from the various elements of the pattern from the vehicle as it moves along the desired path to obtain X-axis errors, angular orientation errors and position along the Y-axis, and correcting the direction of the vehicle from time to time in accordance with the obtained X-axis errors and angular orientation errors when the vehicle departs from the desired path as detected from the recorded locations of geometric points derived from the various elements of the existing pattern.

23. The method of claim 22 further characterized in that the vehicle is substantially continuously maintained on the desired path during unattended movement by