

AUTONOMOUS UNDERWATER VEHICLE (AUV) DOCKING

TECHNICAL FIELD

[0001] The present disclosure relates to systems and methods for docking an Autonomous Underwater Vehicle (AUV).

BACKGROUND

[0002] Autonomous underwater vehicle (AUV) docking technology is a long-term issue in the underwater vehicle research community. A typical system for docking AUVs includes a structure to bring torpedo-shaped cruising vehicles to rest quickly, which is necessary because these vehicles lose controllability at low speed. In one example for docking torpedo-shaped cruising vehicles, compliant cone shapes are usually used to bring the vehicle to rest within one vehicle length or so, which may be a violent deceleration for the vehicle and the internal components of the vehicle.

[0003] Once the AUV is docked, powering and re-charging the AUV is typically performed by rigidly aligning the vehicle to the docking structure for power transfer through traditional underwater connectors or inductive charging. The combination of these requirements has typically resulted in large seafloor installations that often require Remotely Operated Vehicle (ROV) access for installation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 illustrates a system of underwater docking, powering, and communication for an Autonomous Underwater Vehicle (AUV), according to an example embodiment.

[0005] FIG. 2 is a schematic drawing illustrating a bridge circuit for rectifying power drawn from a rotatable power contact, according to an example embodiment.

[0006] FIG. 3A is a perspective drawing showing an electrical contact for providing power/data in an underwater environment, according to an example embodiment.

[0007] FIG. 3B is a cutaway view of the electrical contact of FIG. 3A, according to an example embodiment.

[0008] FIG. 4A is a perspective drawing of an actuating mechanism in an open configuration, according to an example embodiment.

[0009] FIG. 4B is an overhead view of the actuating mechanism of FIG. 4A, according to an example embodiment.

[0010] FIG. 5A is an overhead view of the actuating mechanism in a closed configuration, according to an example embodiment.

[0011] FIG. 5B is a side view of the actuating mechanism of FIG. 5A, according to an example embodiment.

[0012] FIG. 5C is a partial cross-sectional view of a self-insulating contact closed by the actuating mechanism of FIG. 5A, according to an example embodiment.

[0013] FIG. 6 is a perspective drawing of a forward end of an AUV with a captured power cable, according to an example embodiment.

[0014] FIG. 7A is a side view of a self-insulating power cable configured to provide power in an underwater environment, according to an example embodiment.

[0015] FIG. 7B is another side view of the self-insulating power cable, according to an example embodiment.

[0016] FIG. 7C is a cross-sectional view of the self-insulating power cable of FIG. 7A, taken through section B-B, according to an example embodiment.

[0017] FIG. 8A is a head-on view of a self-insulating brush contact, according to an example embodiment.

[0018] FIG. 8B is a cross-sectional view of the self-insulating brush contact of FIG. 8A, taken through section A-A, according to an example embodiment.

[0019] FIG. 9 is a flowchart illustrating a process for an AUV to dock and receive power/data, according to an example embodiment.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

[0020] In some aspects, the techniques described herein relate to an underwater vehicle including: one or more data sensors configured to capture data from an underwater environment; and a docking assembly including: an electrical connector including a plurality of self-insulating brush contacts; an actuator configured to open and close the electrical connector; a position sensor configured to detect the presence of a docking rod within the electrical connector; and a processor configured to cause the actuator to close the electrical connector in response to the position sensor detecting the docking rod within the electrical connector.

[0021] In some aspects, the techniques described herein relate to an underwater vehicle, further including: a battery configured to provide power to the underwater vehicle; and a bridge circuit configured to rectify electrical power provided from the docking rod and charge the battery.

[0022] In some aspects, the techniques described herein relate to an underwater vehicle, wherein the plurality of self-insulating brush contacts include an electrically conductive material selected from a group containing niobium, tantalum, titanium, zirconium, molybdenum, ruthenium, rhodium, palladium, hafnium, tungsten, rhenium, osmium, and iridium

[0023] In some aspects, the techniques described herein relate to an underwater vehicle, wherein the processor is further configured to obtain data from the docking rod through the plurality of self-insulating brush contacts.

[0024] In some aspects, the techniques described herein relate to an underwater dock including: a float; a docking rod connected to the float, the docking rod including: at least two self-insulating contact plates; and a structural member configured to separate the pair of self-insulating contact plates; and a power source configured to provide electrical power to an underwater vehicle through the docking rod.

[0025] In some aspects, the techniques described herein relate to an underwater dock, further including a beacon configured to enable the underwater vehicle to locate the underwater dock.

[0026] In some aspects, the techniques described herein relate to an underwater dock, further including a controller configured to provide data to the underwater vehicle through the docking rod.

[0027] In some aspects, the techniques described herein relate to an underwater dock, further including an anchor configured to secure the underwater dock to a fixed location.

[0028] In some aspects, the techniques described herein relate to an underwater dock, wherein the pair of self-insulating contact plates include an electrically conductive material selected from a group containing niobium, tantalum, titanium, zirconium, molybdenum, ruthenium, rhodium, palladium, hafnium, tungsten, rhenium, osmium, and iridium.

Example Embodiments

[0029] The techniques presented herein provide for a dock that utilizes a self-insulating material to facilitate docking, powering, and communicating with an Autonomous Underwater Vehicle (AUV) with a less violent deceleration of the AUV, the ability for the AUV to approach and dock from any direction, and a smaller sea-floor installation that does not require Remotely Operated Vehicle (ROV) manipulations for installation and service. FIG. 1 illustrates an example of a docking system using the techniques described herein, and shows the relatively small size and weights of the components involved, which allows deployment from the surface without ROV interventions. FIG. 1 shows the dock being powered by a seafloor cable to a nearby power source such as the anchor of a surface buoy or sub-surface power node. However, the dock may also be powered by another method, such as through solar power provided from the surface float or through tidal/wave action.

[0030] Docking is accomplished by outfitting the vehicle with a side hook assembly that catches a vertical rod as the vehicle passes by. In the example embodiment shown in FIG. 1, the side hook assembly is mounted on a side of the AUV near a forward end of the AUV. The distance of the side hook assembly from the forward end is preferably less than half the length of the AUV, and more preferably less than a third of the length of the AUV. The result is that the relatively large amount of kinetic energy of the vehicle is dissipated by deflection in the dock itself, and by the resulting yaw motion of the vehicle as it swings around the vertical mooring

rod. After docking however, the vehicle is not rigidly constrained and is free to float up and down according to how neutrally buoyant it is, and swing around the rod freely in response to currents. The mechanism by which power is transferred in this loosely constrained arrangement relies on the self-insulating material as described below.

[0031] In one example, the contacts of the power connector may be constructed entirely of self-passivating transition metals or they may be constructed of other materials that are coated with self-passivating transition metals. Some examples of materials that are self-passivating in water include niobium, tantalum, titanium, zirconium, molybdenum, ruthenium, rhodium, palladium, hafnium, tungsten, rhenium, osmium, and iridium. Each of these materials react with water to form an electrically insulating passivation layer when exposed to a water environment. The passivation layer may be oxides, hydroxides, or other compounds that form by reacting the self-passivating material with an adverse environment.

[0032] In another example, the housing of the dock controller is preferably constructed to be watertight and to withstand water pressure at the depths at which the dock controller is intended to operate (e.g., on the continental shelf or the ocean floor). The dock controller may include a memory, a processor, and docking logic to enable the dock to provide power and/or data to the AUV as described herein. Similarly, the AUV may include a memory, a processor, and docking logic to enable the AUV to actuate the latching mechanism as described herein and complete the docking process with the dock.

[0033] The memory in the dock controller and/or the AUV is configured to store data, information, software, and/or instructions associated with the docking logic. The memory may store data/information in any suitable volatile and/or non-volatile computer readable storage media (e.g., magnetic hard disk drive, solid state hard drive, semiconductor storage device, random access memory (RAM), read only memory (ROM), erasable programmable read only memory (EPROM), application specific integrated circuit (ASIC), etc.), software, logic (fixed logic, hardware logic, programmable logic, analog logic, digital logic), hardware, and/or in any other suitable component, device, element, and/or object as may be appropriate. Any of the memory items discussed herein should be construed as being encompassed within the broad term "memory." The memory may include non-transitory memory elements, which may store

instructions that are executed to perform one or more of the techniques described herein. Data/information being tracked and/or sent to one or more entities as discussed herein could be provided in any database, table, register, list, cache, storage, and/or storage structure: all of which can be referenced at any suitable timeframe. Any such storage options may also be included within the broad term “memory” as used herein. A “memory” may include one or more memory devices of the type described herein.

[0034] In at least one embodiment, the processor in the dock controller and/or the AUV includes at least one hardware processor configured to execute various tasks, operations and/or functions for the docking process as described herein according to software and/or instructions configured for the dock controller or the AUV. The processor (e.g., a hardware processor) can execute any type of instructions associated with data to achieve the operations detailed herein. In one example, the processor can transform an element or an article (e.g., data, information) from one state or thing to another state or thing. Any of potential processing elements, microprocessors, digital signal processor, baseband signal processor, modem, PHY, controllers, systems, managers, logic, and/or machines described herein can be construed as being encompassed within the broad term 'processor'. In one example, the processor may encrypt/decrypt data or control different levels of Redundant Array of Independent Disks (RAID) in the memory.

[0035] The docking system described herein uses a self-insulating brush arrangement on the vehicle that maintains constant contact with at least two self-insulating electrodes on the docking rod when the vehicle is on the dock. FIG. 2 illustrates a basic electrical concept of an AUV docking connector. Three self-insulating brush contacts disposed on the AUV connect to two self-insulating power contacts on opposite sides of a power cable of the docking system. A bridge circuit rectifies power drawn from the docking rod and provides a consistent positive and negative voltage suitable for charging a battery on the AUV. In one example, additional electrical and/electronic components (e.g., capacitors, inductors, power supply circuitry, etc.) may be added to condition the power received from the docking rod.

[0036] As shown in FIG. 2, using three brush contacts results in electrical current being present in at least two of the three brush contacts as the AUV rotates, and the changing polarity

of the current may be rectified for battery charging by a diode bridge. The “make-before-break” nature of the brush arrangement, and the diode bridge arrangement enable the docking system to provide current through an uninterrupted path. The self-insulating contacts enables the operation of the docking system in water; without the self-insulating properties of this material, an unacceptably large amount of current would short-circuit through the water and energy transfer to the vehicle would be impractical. Technical details of the design include the brush surface area, the spring force that is pushing the brushes against the vertical rod, and the brush arrangement that rectifies the resulting current.

[0037] Power transfer up to 500 Watts has been demonstrated and higher power levels appear possible, limited somewhat by the detrimental arcing that occurs at higher electrical currents. It is expected that these power levels can be increased with a refined brush design, or possibly with a refinement to the self-insulating material. Similarly, brush wear may present challenges when faced with extreme motions of the vehicle on the dock. In addition to power transfer, digital communications may be provided alongside the power on these conductors. Additional refinement of the electrical contacts and/or the communication circuitry may be included in the docking system and/or the AUV to contend with noise issues from an at-sea deployment.

[0038] FIGs. 3A and 3B illustrate an electrical connector with self-insulating, spring-loaded brushes operationally coupled to a docking rod with self-insulating contacts. In the electrical connector shown in FIGs. 3A and 3B, the self-insulating, spring-loaded brushes are mounted in a pair of jaws configured to capture the docking rod therebetween when brought together. For example, inner surfaces of the jaws may have a curved configuration that defines a hollow cylindrical space between the jaws when the jaws are mated together. The hollow cylindrical space between the jaws may be slightly larger than the diameter of the docking rod so that a small gap is defined between the jaws and the docking rod when the jaws are brought together. The electrical connector is thus free to rotate around the docking rod and translate up and down the docking rod. In an embodiment, rollers may be mounted on the jaws of the electrical connector to engage the docking rod and facilitate movement of the electrical connector relative to the docking rod. For example, rollers may be mounted at upper and lower ends of the jaws to rotate about axes perpendicular to a longitudinal axis of the docking rod to facilitate translation

of the electrical connector up and down the docking rod, even if the electrical connector is rocking back and forth due to movement of the AUV in the underwater environment. Rollers may also be mounted to rotate about axes parallel to the longitudinal axis of the docking rod to facilitate rotation of the electrical connector about the longitudinal axis of the docking rod.

[0039] In the electrical connector shown in FIGS. 3A and 3B, the jaws are configured to define a generally cylindrical, hollow tubular structure when brought together. In this embodiment, one of the jaws forms approximately 2/3 of the cylinder, and the other jaw forms approximately 1/3 of the cylinder. However, it will be appreciated that the jaws may each form $\frac{1}{2}$ of the cylinder, or each jaw may form other fractions of a cylinder, so long as when they are brought together, the two jaws define a space suitable to capture the docking rod therebetween. While, in the illustrated embodiment, the two jaws combine to completely encircle the docking rod, it will be appreciated that the two jaws need not completely encircle the docking rod so long as any circumferential gap between the jaws is smaller than the diameter of the docking rod.

[0040] The cutaway view of FIG. 3B shows the self-insulating, spring-loaded brushes that make electrical contact with the self-insulating contacts on the docking rod. The electrical connector of FIGS. 3A and 3B is shown with three equally spaced self-insulating brushes that extend radially through the jaws of the electrical connector relative to the longitudinal axis of the docking rod, but other configurations are also envisioned. For instance, other numbers of self-insulating brushes may be included. Additionally, the self-insulating brushes may be configured in sets of brushes for redundancy. In general, the size and number of the self-insulating brushes on the electrical connector are designed along with the size and separation of the self-insulating contact plates on the docking rod to ensure that at least one self-insulating brush remains in contact with a self-insulating contact plate of each polarity, and to ensure that a single self-insulating brush contact does not bridge the two contact plates of the docking rod.

[0041] FIGS. 4A-5C illustrate an example embodiment a side hook assembly to catch/retain the vertical rod and establish electrical contact therewith. The side hook assembly shown in FIGS. 4A-5C includes an actuating mechanism configured to mount on the side of the AUV and to open and close the jaws of the electrical connector. FIG. 4A illustrates an open configuration of the actuating mechanism configured to latch and unlatch an electrical connector between an

AUV and a docking rod that provides power/data to the AUV. A mounting block with a fixed jaw portion of the electrical connector is attached to the AUV. The actuator operates a linkage to open an actuated arm holding an actuated jaw portion of the electrical connector and allow the docking rod to enter or leave the electrical connector. The fixed jaw and the actuated jaw portions of the electrical connector include one or more self-insulating, spring loaded brush contacts that make electrical contact with the self-insulating contacts on the docking rod. The actuated jaw portion of the electrical connector is attached to an actuated arm that may serve to capture the docking rod and guide the docking rod into position as the AUV moves forward in the underwater environment. FIG. 4B shows an overhead view of the actuating mechanism of FIG. 4A.

[0042] FIG. 5A illustrates an overhead view of the actuating mechanism in a closed configuration. Once the docking rod has been captured and positioned by the actuated arm, the actuator pushes the linkage to close the actuated jaw and secure the docking rod in the electrical connector. For clarity, the docking rod is not shown in FIG. 5A, FIG. 5B, or FIG. 5C.

[0043] FIG. 5B shows a side view of the actuating mechanism in a closed configuration. The actuated jaw shown in FIG. 5B includes a pair of two self-insulating brushes that are configured to contact the same self-insulating contact on the docking rod, but at points that are spaced vertically along the docking rod. In one example, the fixed jaw may have similar sets of self-insulating brushes. Including sets of brush contacts may provide a redundant electric path to improve the reliability of the electrical connector.

[0044] An optical sensor housing holding an optical sensor is attached to the mounting block and detects when the docking rod is positioned within the jaws of the electrical connector. In one example, the optical sensor may actively send out a sensor beam and detect a reflection off the docking rod when the docking rod is in place. Alternatively, if sufficient ambient light is available (e.g., if the AUV and docking rod are close to the surface of the water), the optical sensor may detect the docking rod obscuring the ambient light when the docking rod is in position to be captured by the actuated jaw. In another example, non-optical (e.g., capacitive, acoustic, etc.) sensors may be used to detect the position of the docking rod as it approaches the electrical connector to determine when to actuate the jaw and capture the docking rod.

[0045] FIG. 5C shows a cutaway view of the actuating mechanism in a closed configuration. The spring-loaded, self-insulating brushes in the fixed jaw and the actuated jaw allow the electrical connector to shift while maintaining electrical contact with the docking rod. The strength of the spring may be designed to optimize how tightly the brushes are held against the self-insulating contacts on the docking rod, which may affect the amount of current that the AUV may draw from the docking rod. Additionally, the strength of springs holding the self-insulating brushes against the self-insulating contacts of the docking rod may affect the wear characteristics of the docking rod and the brushes. For instance, pressing the self-insulating brushes and contacts together harder may allow a higher current to power the AUV, but also increase the wear on the self-insulating material, requiring more frequent replacement of the self-insulating brushes.

[0046] FIG. 6 shows an example of an AUV connected to a docking rod with the side hook assembly described herein. The side hook assembly, including the actuating arm, the electrical connector, and the optical sensor, is mounted on the side of the AUV to promote a yaw motion of the AUV to decelerate and dissipate the kinetic energy of the AUV in the docking process. Mounting the electrical connector on the side of the AUV also preserves the availability of the nose area of the AUV for sensors. The nose of the AUV may also include one or more guides to direct the docking rod toward the side with the electrical connector.

[0047] In one example of the AUV docking and receiving power/data from the dock, the AUV locates the dock and moves forward toward the dock. For instance, the AUV may detect a beacon (as shown in FIG. 1) that emits acoustic and/or optical signals that identify the dock. Once the AUV has roughly located the dock, the UAV opens the actuating arm and moves forward until the nose, or the guide mounted on the nose, contacts the docking rod and pushes the docking rod toward the actuating arm. The actuating arm guides the docking rod to the appropriate position with the electrical connector.

[0048] Once the optical sensor detects the docking rod in the appropriate position, the actuating mechanism closes the actuating arm and secures the docking rod in the electrical connector. The actuating mechanism may wait until the optical sensor detects the docking rod in the proper position for at least a predetermined minimum length of time before closing the

actuating arm to prevent a false positive or transient detection from closing the electrical connector before the docking rod is secured in the appropriate position.

[0049] Closing the actuating arm and securing the AUV to the docking rod causes the AUV to maintain position with the dock. The docking rod is not typically rigidly connected to the seafloor, and the docking rod may move with the AUV as the AUV is decelerating. Connecting the docking rod to the side of the AUV may also cause the AUV to spin around the docking rod as the kinetic energy of the AUV is dissipated. Allowing the docking to move and allowing the AUV to yaw around the docking rod lowers the magnitude of the deceleration experienced by the AUV.

[0050] After the electrical connector has captured the docking rod in the docking process, the dock may begin to supply electrical power and/or data through self-insulating contacts on the docking rod. The AUV and the dock are not rigidly connected, which allows the AUV to rotate around the docking rod (e.g., as the tides and/or currents shift) and move up and down the docking rod (e.g., in response to changes in buoyancy of the AUV). The self-insulating material on the docking rod and the brushes on the electrical connector of the AUV enable a low resistance electrical contact where the docking rod and brushes physically meet to abrade the insulating layer. When the AUV moves relative to the docking rod (e.g., rotates or translates), the self-insulating material is exposed to the water environment and re-forms the insulating layer, which prevents discharge through the water.

[0051] FIG. 7A illustrates a side view of the docking rod with self-insulating material to provide power to an AUV. The docking rod includes two contact plates made from a self-insulating material that forms an insulating surface layer when exposed to water. The two contact plates are separated by an insulating gap, which may be filled with non-conductive material. In one example, the two self-insulating contact plates may be formed by cutting grooves along the length of a tube of self-insulating material. In another example, the docking rod may include an insulating core (e.g., polyvinyl chloride (PVC), fiberglass, insulating tube over wire-rope strength member, etc.) supporting the self-insulating material of the contact plates.

[0052] FIG. 7B illustrates a rotated side view of the docking rod that shows anchor points on opposite ends of the docking rod. The docking rod and the self-insulating contact plates may

extend for a relatively small length of the overall docking system (e.g., 2 meters as shown in FIG. 1). The anchor point at a first end of the docking rod structurally connects the docking rod to the seafloor anchor through the dock controller. The anchor point at a second end opposite the first end of the docking rod structurally connects the docking rod to the buoyant float. In the example embodiment shown in FIGS. 7A-C, the anchor points are shown as eye bolts; however, any suitable combination of anchoring elements can be used.

[0053] FIG. 7C illustrates a cutaway view of the docking rod showing an example of the interior structure of the docking rod. The anchor points are connected to the insulating core, e.g., to provide the structural support of the docking rod in the docking system. In one example, the insulating core may include one or more strength members (e.g., stiffening rods) to provide additional structural support to the docking rod. The self-insulating power contacts are electrically connected through terminal contacts to electrical wires (not shown). In one example, the electrical wires are attached to the self-insulating power contacts through a physical connection (e.g., crimping, set screws, etc.). Additionally, the electrical connection between the electrical wires and the self-insulating contact plates may be made by other processes (e.g., soldering, welding, brazing, conductive adhesive, etc.). To protect the connection between the electrical wires and the self-insulating contact plates from the underwater environment, the ends of the docking rods may be sealed with a watertight, insulating potting compound.

[0054] FIG. 8A illustrates an end view of a brush contact assembly used in the electrical connector described herein. The brush contact assembly is shown with a circular cross-section in FIG. 8A, but other cross-sections (e.g., oval, polygonal, irregular, etc.) are also envisioned. FIG. 8B shows a cutaway side view of the brush contact assembly with the connection of the self-insulating brush contact to an electrical wire. The brush contact assembly includes a spring configured to force the self-insulating brush contact into the self-insulating contact plate of the docking rod. A washer enables rotational movement between the spring and the self-insulating brush contact.

[0055] The brush contact assembly shown in FIG. 8B includes a deformable, conductive crimp insert that secures the electrical wire and provides a stable electrical connection between the electrical wire and the self-insulating brush contact. In one example, additional materials

(e.g., solder, conductive adhesive, etc.) may further solidify the electrical connection between the crimp insert, the self-insulating brush contact, and the electrical wire. The electrical connection may be sealed with a watertight, insulating potting compound to protect the connection from the environment.

[0056] FIG. 9 is a flowchart illustrating an example process 900 of operations performed at an underwater vehicle (e.g., the AUV shown in FIG. 1) to receive power and/or data from an underwater dock. At 910, the vehicle detects the underwater dock. In one example, the vehicle detects a beacon on the underwater dock and navigates toward the beacon. Once the vehicle is close to the underwater dock, the vehicle opens an actuating arm of an electrical connector at 920.

[0057] At 930, the vehicle detects when a docking rod is in an appropriate position between the jaws of the electrical connector. In one example, the vehicle includes an optical sensor that detects the optical rod. In another example, the vehicle may wait until the docking rod is in the jaw for a predetermined minimum amount of time (e.g., five seconds) before determining that the docking rod is in the appropriate position of the jaw. In an example embodiment, if the vehicle does not detect the optical rod in the jaw after a predetermined maximum amount of time, the AUV controller may determine that the side hook assembly has failed to capture the docking rod. In this example, the AUV may turn around and attempt to approach the docking rod again. For instance, the AUV may navigate to approach the underwater dock from a different direction (e.g., facing into a water current instead of facing across the water current), which may provide a more consistent approach to the underwater dock.

[0058] After the docking rod is in the appropriate position, as determined at 930, then the vehicle closes the actuating arm at 940 and secures the jaw of the electrical connector on the docking rod. In one example, securing the jaw of the electrical connector on the docking rod limits the motion of the vehicle and causes the vehicle to decelerate and remain attached to the docking rod. Additionally, the jaw may be positioned on the side of the vehicle, enabling the vehicle to spin around the docking rod.

[0059] At 950, the vehicle receives electrical power and/or data from the underwater dock through the self-insulating brushes in the jaw of the electrical connector. In one example, the

vehicle may maintain the electrical connection with the docking rod while rotating around the docking rod and/or translating along the length of the docking rod.

[0060] In summary, the techniques presented herein enable an AUV to exchange data and recharge from an underwater dock using an electrical connector with self-insulating contacts. The positioning of the connection between the AUV and the dock reduces the sudden deceleration of docking by allowing the dock itself to move and by allowing the AUV to rotate around the dock to dissipate kinetic energy and momentum. The self-insulating material used in the electrical connection between the AUV and the dock enables a low resistance electrical connection while preventing leakage through the underwater environment.

[0061] Methods and systems are disclosed herein with the aid of functional building blocks illustrating functions, features, and relationships thereof. At least some of the boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries may be defined so long as the specified functions and relationships thereof are appropriately performed. While various embodiments are disclosed herein, it should be understood that they are presented as examples. The scope of the claims should not be limited by any of the example embodiments disclosed herein.

[0062] What has been described above are examples. It is, of course, not possible to describe every conceivable combination of components or methodologies, but one of ordinary skill in the art will recognize that many further combinations and permutations are possible. Accordingly, the disclosure is intended to embrace all such alterations, modifications, and variations that fall within the scope of this application, including the appended claims. As used herein, the term “includes” means includes but not limited to, the term “including” means including but not limited to. The term “based on” means based at least in part on. Additionally, where the disclosure or claims recite “a,” “an,” “a first,” or “another” element, or the equivalent thereof, it should be interpreted to include one or more than one such element, neither requiring nor excluding two or more such elements.

What is claimed is:

1. An underwater vehicle comprising:
 - one or more data sensors configured to capture data from an underwater environment;
 - and
 - a docking assembly comprising:
 - a hook assembly mounted on a side of the underwater vehicle, the hook assembly including an electrical connector including a pair of jaws holding a plurality of self-insulating brush contacts;
 - an actuator configured to open and close the pair of jaws of the electrical connector;
 - a position sensor configured to detect a docking rod within the electrical connector; and
 - a processor configured to cause the actuator to close the electrical connector in response to the position sensor detecting the docking rod within the electrical connector.
2. The underwater vehicle of claim 1, further comprising:
 - a battery configured to provide power to the underwater vehicle; and
 - a bridge circuit configured to rectify electrical power provided from the docking rod and charge the battery.
3. The underwater vehicle of claim 1, wherein the plurality of self-insulating brush contacts comprise an electrically conductive material selected from a group containing niobium, tantalum, titanium, zirconium, molybdenum, ruthenium, rhodium, palladium, hafnium, tungsten, rhenium, osmium, and iridium.
4. The underwater vehicle of claim 1, wherein the processor is further configured to obtain data from the docking rod through the plurality of self-insulating brush contacts.

5. An underwater dock comprising:
a float;
a docking rod connected to the float, the docking rod comprising:
at least two self-insulating contact plates; and
a structural member configured to separate the at least two self-insulating contact plates; and
a power source configured to provide electrical power to an underwater vehicle through the docking rod.
6. The underwater dock of claim 5, further comprising a beacon configured to enable the underwater vehicle to locate the underwater dock.
7. The underwater dock of claim 5, further comprising a controller configured to provide data to the underwater vehicle through the docking rod.
8. The underwater dock of claim 5, further comprising an anchor configured to secure the underwater dock to a fixed location.
9. The underwater dock of claim 5, wherein the at least two self-insulating contact plates comprise an electrically conductive material selected from a group containing niobium, tantalum, titanium, zirconium, molybdenum, ruthenium, rhodium, palladium, hafnium, tungsten, rhenium, osmium, and iridium.
10. A method as shown and described herein.
11. A system as shown and described herein.
12. One or more computer readable storage media encoded with software comprising computer executable instructions and when the software is executed operable to perform operations shown and described herein.

ABSTRACT

An underwater docking system enables an underwater vehicle to receive power and data through self-insulating contacts. The electrical connector on the underwater vehicle allows the underwater vehicle to maintain an electrical connection with the underwater dock without locking the vehicle rigidly to the dock. The underwater vehicle may rotate around the docking rod of the underwater dock and translate the length of the docking rod without losing the electrical connection with the underwater dock.