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(54) **SYSTEM FOR ENHANCING CORROSION PROTECTION OF A MARINE STRUCTURE**

(57) A system (100) is provided for protecting enhancing corrosion protection of a protected surface (30) of a marine structure (110) in contact with a liquid containing biofouling organisms. The protected surface is electrically conductive and being protected against corrosion by impressed current cathodic protection. The system (100) has a light emitting arrangement (20) having a light source for emitting anti-fouling light (22) to illuminate a zone of the protected surface (30). A detector (23) generates level data indicative of the level of the liquid line, and a controller (21) controls the intensity of the anti-fouling light at the zone in dependence of the level data. The intensity may be increased when the level is below a time-averaged level of the liquid line.

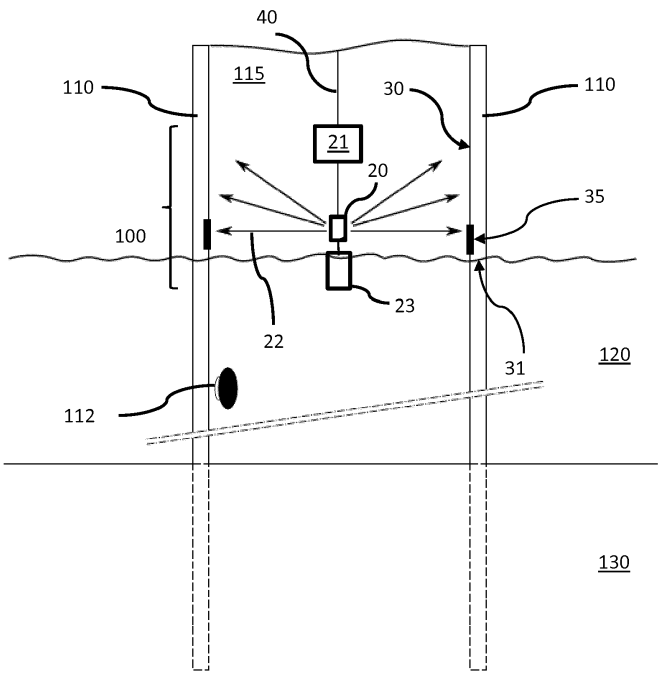

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The invention relates to methods, systems and devices for enhancing corrosion protection of a protected surface of a marine structure in a liquid containing biofouling organisms. Marine structures are metallic structures in various wet environments such as pipelines, wind turbines, steel pier piles, offshore oil platforms, offshore wind farm foundations, monopiles for wind turbines, non-monopile supports for wind turbines, oil rigs, structures for harvesting tidal energy and/or wave energy, etc. The liquid containing biofouling organisms may be any an aqueous or oily environment, in particular sea water. In general, corrosion causes such constructions to weaken. Corrosion may be accelerated by biofouling, which may cause so-called pit corrosion. The invention may be applied for reducing or preventing corrosion of such marine structures in contact with the liquid.

BACKGROUND OF THE INVENTION

[0002] Cathodic protection makes an electrically conductive surface act as a cathode, which is a technique used to reduce corrosion of a metal surface by making it the cathode of an electrochemical cell. A passive method of protection connects the metal to be protected to a more easily corroded sacrificial metal to act as the anode. The sacrificial metal then corrodes instead of the protected metal. For various reasons, passive galvanic cathodic protection may not be adequate.

[0003] An external DC electrical power source may be used to provide sufficient current to cause a potential of the protected surface with respect to the liquid required to prevent corrosion. Using this method is usually called impressed current cathodic protection (ICCP). Impressed current cathodic protection systems may protect a wide range of marine structures. ICCP is aiming at stopping corrosion by creating a potential on the metal to be protected; the potential required being 0.8-0.9 V.

SUMMARY OF THE INVENTION

[0004] It follows from the foregoing that impressed current cathodic protection measures are known to effectively reduce corrosion of immersed and even buried protected surfaces. However, at some protected surfaces of a partly immersed marine structure protected by impressed current cathodic protection, corrosion still poses a problem.

[0005] The invention has as an object to enhance protection of against corrosion of surfaces of a marine structure in contact with a liquid containing biofouling organisms.

[0006] According to the invention, a system is provided for enhancing corrosion protection of a protected surface of a marine structure in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive and being protected against corrosion by impressed current cathodic protection. The system comprises

a light emitting arrangement comprising a light source for emitting anti-fouling light, the light emitting arrangement being arranged to illuminate, by the anti-fouling light, a zone of the protected surface,

a detector for generating level data indicative of the level of the liquid when the marine structure is partly immersed in the liquid, and

a controller for controlling the intensity of the anti-fouling light at the zone in dependence of the level data.

[0007] According to another aspect of the invention, a marine structure, especially a support structure for a sea-based wind turbine, has a protected surface arranged to be electrically conductive to be protected against corrosion by impressed current cathodic protection when in contact with a liquid containing biofouling organisms, the marine structure comprising the above system.

[0008] According to another aspect of the invention, there is provided a method of enhancing corrosion protection of a protected surface of a marine structure in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive, the method comprising

providing impressed current cathodic protection via the protected surface,

illuminating, by anti-fouling light from a light emitting arrangement, a zone of the protected surface,

generating level data indicative of the level of the liquid when the marine structure is partly immersed in the liquid, and

controlling the intensity of the anti-fouling light at the zone in dependence of the level data.

[0009] The above features have the effect that, when the invention is put to practice, the anti-fouling light reaches the zone of the protected surface at an intensity controlled in dependence of the level data. Advantageously, the intensity is controlled so as be sufficient to effectively reduce bio-fouling while using an appropriate amount of power.

[0010] The marine structure is protected against corrosion by impressed current cathodic protection (ICCP), requiring the protected surfaces to be electrically conductive and in contact with the liquid. However, the inventors have found that corrosion still occurs, and that a reason for this might be biofouling. The ICCP reduces corrosion but may be rendered less effective by biofouling. Biofouling has been found to locally reduce effectiveness of ICCP working at the normal operational voltage range of 0.8 to 0.9 V. So, accelerated corrosion may occur due to the influence of microbes at a surface protected by ICCP. Killing or keeping at a distance such bacteria has been found to be necessary to maintain the effects of ICCP. This has been achieved by combining ICCP and the light source emitting the anti-fouling light towards the zone of the protected surface. The anti-fouling light, e.g. UV(C), which is controlled to have at least a predetermined intensity at the zone, will reduce biofouling so that ICCP can continue protecting the protected surface against corrosion.

[0011] The zone may comprise a part, usually called tidal part or a splash part, located at the level of the liquid when the marine structure is partly immersed in the liquid, usually called the liquid line. The tidal part is the part covering varying liquid levels due to tides. The splash part, just above the waterline at the outside of marine structures, may be exposed intermittently to both water and air, for example due to waves.

[0012] In the system, the light emitting arrangement may be constructed or positioned to emit the anti-fouling light from the light source towards a zone at or around the liquid line, e.g. the zone having said tidal part and/or splash part. The ICCP system relies on the electric conductivity of water, but is not effective above the waterline. Any dry metal part above the surface of the liquid is not protected as no current can flow. In addition, the inventors have found that the impressed current cathodic protection is less effective on protected surfaces that are wetted intermittently, for example, protected surfaces of partly immersed marine structures may be wetted regularly but not constantly due to a varying water line of sea water due to waves, tides or currents. Bacteria may be abundant in thin films of water which are drying up. By applying anti-fouling light like UV light on a zone at the liquid line, such fouling is prevented and accelerated corrosion in the tidal and/or splash parts is reduced. In such zones, which are particularly prone to corrosion due to fouling, accelerated corrosion is effectively prevented by ICCP in combination emitting the anti-fouling light towards such parts.

[0013] Also, surfaces just below the waterline may be prone to biofouling which reduces efficiency of ICCP. The zone may comprise a submerged part located just below the level of the liquid. Biofouling is prevented by providing the anti-fouling light on the submerged part at sufficient intensity to kill or keep at a distance bacteria to reduce or prevent microbial induced corrosion. Advantageously the submerged parts of the zone remain accessible for ICCP due to the anti-fouling light that keeps the submerged parts free of biofouling.

[0014] The detector may be constructed to detect the level of the liquid, and/or to receive data that enables deriving the liquid level, and is constructed to generate the corresponding level data. For example, the detector may have a liquid level sensor that detects the level with reference to a fixed point, or a sensor that detects whether the level exceeds a predetermined threshold, or one or more of multiple thresholds at various heights. The detector may alternatively, or additionally, be arranged to detect that the light source is above or under water. Also, the detector may include an absorption or transmission detector. The controller may subsequently control the light intensity to compensate for absorption.

[0015] The controller is arranged to control the intensity of the anti-fouling light at the zone in dependence of the level data. For example, the controller may adjust the position or height of the light source, and/or the electrical power to the light source, to provide the anti-fouling light at a required intensity at the zone. Also, the controller may switch on the light source for controlled periods, and/or adjust the amount of anti-fouling light at the zone, in dependence of the level data. In dependence of the level data indicating that the liquid level is low, the anti-fouling light may be controlled to be more intense.

[0016] In an embodiment, the controller is arranged to control the light source in dependence of the liquid level falling below a predetermined threshold. If so, the light source may be switched on or the intensity may be increased. Also, the intensity of the light source may be adjusted by the controller so that the intensity of the anti-fouling light arriving on a specific zone, e.g. at or around the liquid line, is substantially constant.

[0017] Optionally, the intensity on the zone at the liquid line is controlled to be higher when the level of the liquid is below a time-averaged level of the liquid. Part of the zone just above the lowest liquid line, e.g. above the liquid line when the level is below a time-averaged level of the liquid, may be prone to accelerated fouling when it is still wet. The controller may increase the intensity while the liquid level is low and such part is illuminated, thereby ensuring a sufficient dose of light over time at such part of the zone.

[0018] In an embodiment, the system comprises an adjuster arranged to adjust the position of the light source, and the controller is arranged to be coupled to the adjuster and to control the intensity of the anti-fouling light at the zone by adjusting the position in dependence of the level data. The position of the light source may be adjusted in at least a vertical direction with respect to the liquid surface, for example to follow variations of the liquid level, e.g. due to tides. Advantageously, the light source may be kept at a required position near a part of zone that is wetted intermittently. Also, the light source may be moved by the adjuster horizontally, or by a combination of movements, to be within a predetermined distance range from various parts of the zone to control the intensity of the anti-fouling light at the zone.

[0019] Optionally, the controller is arranged to control the power of the anti-fouling light as emitted in dependence of the level data for controlling the intensity of the anti-fouling light at the zone. Effectively, the intensity is adjusted to follow vertical variations of the liquid level. The amount of power provided to the light source is reduced when the liquid level is high, while more power is provided when the level is low. Advantageously the total required power is reduced, compared to an uncontrolled system where intensity must be high at all times. Also, the light source may remain at a fixed height, or may additionally be moved by the adjuster as described above.

[0020] Optionally, the system comprises a guidance element for coupling the light emitting arrangement to the marine structure and arranged to have the light emitting arrangement move via the guidance element in dependence of the level data. For example, the guidance element may be a rod movably coupled to the marine structure. Advantageously the position of the light emitting arrangement is now controlled via the guidance element.

[0021] In an embodiment, the light emitting arrangement may be shaped to movably fit within an inner space of the marine structure, the protected surface being formed by the inner surface of walls of the inner space, and the guidance element is a cable. Advantageously, in use, the light emitting arrangement is positioned via the cable and the inner surface of the marine structure receives the anti-fouling light, e.g. near the liquid line where ICCP is less effective.

[0022] Optionally, the system comprises an electrode to be coupled to the guidance element and to be submerged in the liquid, and the impressed current cathodic protection is arranged to provide an electric current between the electrode and the protected surface. Advantageously, mounting the electrode on the guidance element is easy compared to mounting the electrode on the marine structure itself while isolating the electrode and connecting the electrode to an ICCP power source for providing said impressed current.

[0023] In an embodiment, the light emitting arrangement comprises a float for positioning the device relative to the zone to receive anti-fouling light, e.g. at the surface of the liquid. During floating the floater device may be kept within a distance from the protected surface, for example, by a few bumpers, buffers or fenders at the outer boundary of the device at the device liquid line, and/or a cable or pole movably coupled between the floater device and the marine structure or some fixed point. Advantageously the floater device follows the level of the liquid line.

[0024] Optionally, the controller may be arranged to have the floater device irradiate the protected surface when the liquid level is below a predetermined threshold. For example, the position of the floater device may be detected to detect when the liquid level is below said threshold. Also, a floater device may have at least one light source on its underside, i.e. during use submerged in the liquid. In a practical embodiment, a light source may be attached to the float, e.g. on the upper side or the underside of the float, the whole arrangement being held in place by a cable or pole. Also, the intensity of the light source may be gradually or stepwise increased when the level is becoming lower so as to more intensely illuminate the surface that is still wet just above the liquid line.

[0025] In an embodiment, the light emitting arrangement comprises a rotator element for rotating the light emitting arrangement with respect to the marine structure due to variations of the level of the liquid. For example, the rotator element is rotationally coupled to an element that is fixed to the marine structure. Optionally, one or more light sources are arranged on, or near the outer boundary of, the light emitting arrangement and may be moved along the protected surface due to the rotation of the light emitting arrangement with respect to the marine structure. Advantageously, shadows cast by protruding elements of the marine structure may vary in shape and location, so that all of the protected surface is illuminated for some time during the rotational movement. In a practical embodiment, the rotator element may comprise a propeller or screw shaped element for, in use, being immersed in the liquid and being kept at a predefined height with respect to the marine structure. Due to the tides the water level varies and the propeller or screw will rotate. Optionally, the rotator element comprises a worm type interface to the guidance element as described above, for example cork screw stick.

[0026] Optionally, the impressed current cathodic protection is arranged to provide an electric current between the protected surface and an electrode submerged in the liquid, and the system comprises a power arrangement arranged to power the light source from the electric current. Advantageously, the power arrangement achieves that a power source providing the electric current for the impressed current cathodic protection is now shared for also providing the power to the light source.

[0027] Optionally, the controller is arranged to operate the light source to emit the anti-fouling light when the liquid level is below a predefined level. For example, the light source is operated around the time the liquid is at its lowest. Optionally, the light source is arranged to be mounted so that it becomes exposed when the liquid level is below a predefined level, the detector is arranged to assess whether or not the light source has become exposed and the controller is arranged to operate the light source correspondingly. Correspondingly means that the intensity of the light source is adjusted to the light source being exposed or not. For example, the intensity of the light source is increased, or turned on from zero to full intensity, when the light source is exposed. Advantageously, when the light source is exposed, the anti-fouling light can easily reach the zone and will have a relative high intensity at the zone as the absorption of air is low. In an embodiment, the light source is only turned on when the liquid level is close to its lowest level. Advantageously, in air there is little UV absorption and, around the moment of low tide, the entire tidal zone is exposed. Furthermore, the light source may be switched on or switched to a high intensity for a short period when submerged, to compensate for the high absorption of the liquid and reduce biofouling during submerging of the zone, and/or to prevent biofouling of the light source itself.

[0028] Optionally, the light source is arranged to be at a distance above the liquid and the controller is arranged to operate the light source to emit the anti-fouling light when the liquid level is below a predefined level. For example, the light source is operated around the time the liquid is at its lowest. Advantageously, the zone just below the lowest level is then reached by UV penetrating a relatively short distance through the liquid, with relatively low losses in UV intensity.

[0029] Optionally, the light source is arranged to be at a distance above the liquid to emit at least a part of the anti-fouling light at an angle towards the surface of the liquid so that the part of the anti-fouling light reaches a submerged part of the zone and the controller is arranged to operate the light source to emit the anti-fouling light when the liquid level is below a predefined level. For example, the light source is operated around the time the liquid is at its lowest. Advantageously, the zone just below the lowest level is then reached by UV penetrating a relatively short distance through the liquid, with relatively low losses in UV intensity.

[0030] In practice the light source may be adapted to emit ultraviolet light. A general advantage of using ultraviolet light for realizing anti-biofouling is that the microorganisms are prevented from adhering and rooting on the surface to be kept clean, without harmful side effects.

[0031] Optionally, the controller is arranged to control the impressed current cathodic protection. Advantageously, a combined controller may be arranged to control both the ICCP and the anti-fouling light, which reduced the number of elements of the system that need to be installed and coupled.

[0032] Optionally, the controller may be arranged to control the intensity of the anti-fouling light in dependence of the impressed current cathodic protection. For example, the controller may optimize the combined effect of ICCP and the anti-fouling light, e.g. by increasing the ICCP current in dependence of the level data indicating that the liquid level is high. Also, the controller may be arranged to control, in dependence of the level data indicating that the liquid level is low, the strength of the electric current between the protected surface and an electrode immersed in the liquid to be less.

[0033] Also, when controlling the ICCP based on controlling the potential at the protected surface to be at an operational value, e.g. 0.85 V, the resulting current may be detected by the controller and may be used to determine whether the level of the liquid is low, as less current will be required at low liquid levels. Also, the detected current may be used to directly control the light source so that at lower detected currents the intensity is increased, e.g. complementary stepwise adapting the intensity of the anti-fouling light, or switching on the light source when the current is below some preset level. The controller may receive current data from an ICCP system and subsequently control the anti-fouling light when the current data indicates a reduction in efficiency of the ICCP.

[0034] In a combination of the above, when the liquid level is low, the controller may control the anti-fouling light to be more intense, while controlling the strength of the electric current to the part of the protected surface that is in contact with the liquid to be smaller. In the embodiment, at low levels, the amount of power for the light source is increased while the amount of power for the impressed current cathodic protection is decreased. So, effectively, the total required power capacity of the power source is reduced compared to a system that has the electric power and/or the light intensity at a high level independent of the liquid level.

[0035] Optionally, the above system as comprises an impressed current unit for providing the impressed current cathodic protection of the protected surface. Advantageously, controlling and/or powering the ICCP and the light source may be combined.

[0036] The invention is applicable in various contexts of in marine structures, which then comprise the above system. For example, the system according to the invention may be applied to a monopile carrying a wind turbine, or a marine vessel. The marine structure has a surface to be protected against corrosion when in contact with a liquid containing biofouling organisms. The protected surface is electrically conductive and is to be protected by impressed current cathodic protection, while the marine structure comprises the above described system to enhance the efficiency of ICCP by the anti-fouling light being controlled in dependence of the level data.

[0037] Also, use of the above system is foreseen for enhancing corrosion protection of a protected surface of a marine structure when partly immersed in a liquid containing biofouling organisms. The use comprises providing impressed current cathodic protection via the protected surface which is electrically conductive, powering the light source to emit the anti-fouling light towards the zone, generating the level data and controlling the intensity of the anti-fouling light in dependence of the level data.

[0038] The above-described and other aspects of the invention will be apparent from, and elucidated with reference to, the following detailed description of embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] These and other aspects of the invention will be apparent from and elucidated further with reference to the embodiments described by way of example in the following description and with reference to the accompanying drawings, in which

Fig. 1 shows an example of a system for enhancing corrosion protection of a protected surface,

Fig. 2 shows an example of a system for enhancing corrosion protection having a height adjuster,

Fig. 3 shows schematically an electrical circuit of a protection system,

Fig. 4 shows schematically an example of an electrical circuit of a protection system having a power arrangement, and

Fig. 5 shows an example of a system for enhancing corrosion protection having a rotator.

[0040] The figures are purely diagrammatic and not drawn to scale. In the figures, elements which correspond to elements already described may have the same reference numerals.

DETAILED DESCRIPTION OF EMBODIMENTS

[0041] To counter natural corrosion of a steel marine structures, surfaces may be coated or painted and are in addition often equipped with passive or active cathodic protecting systems such that the structure remains protected against natural corrosion even when the protective coating fails locally. Passive systems use sacrificial Zinc, Aluminum or Iron anodes that dissolve electro-chemically over time, whereas active systems impress a DC current in using anodes made of MMO-Ti (mix metal oxides) coated Titanium or Pt/Ti (Platinum coated Titanium). Active systems like impressed current cathodic protection (ICCP) impress a DC current into the sea water, while careful monitoring is required as too large currents may dissolve the hull locally at enhanced rates. The current document focuses on improving active impressed current cathodic protection, working at the normal operational voltage range of 0,8 to 0,9 V.

[0042] The impressed current cathodic protection (ICCP) may reduce corrosion. However, ICCP may only work under water and if the metal is not insulated from the current. It has been found that accelerated corrosion may be caused by microbial organisms in marine structures, even if they are protected by ICCP. As ICCP may not sufficiently protect some areas against corrosion, it is proposed to provide anti-fouling light like UVC to complement the ICCP. Anti-fouling light is effective above the water and may prevent biofilms causing insulation of electrical currents under water. Combination of ICCP with UVC radiation enhances the protection, for example by reaching areas where ICCP doesn't work and keeping areas free of biofilms, which otherwise would block the ICCP system.

[0043] Biofouling of surfaces which are exposed to water, during at least a part of their lifetime, is a phenomenon known as such, which causes substantial problems in many fields. For example, in the field of shipping, biofouling on the hull of ships is known to cause a severe increase in drag of the ships, and thus increased fuel consumption of the ships. Users of ICCP on stationary marine structures are, as such, not interested in antifouling measures as fouling per se does not pose a problem to them. For instance, support structures for sea-based wind turbines do not suffer from increased drag due to macro-fouling as ships do.

[0044] In general, biofouling is the accumulation of microorganisms, plants, algae, small animals and the like on surfaces. According to some estimates, over 1,800 species comprising over 4,000 organisms are responsible for biofouling. Hence, biofouling is caused by a wide variety of organisms, and involves much more than an attachment of barnacles and seaweeds to surfaces. Biofouling is divided into micro fouling which includes biofilm formation and bacterial adhesion, and macro fouling which includes the attachment of larger organisms. Due to the distinct chemistry and biology that determine what prevents them from settling, organisms are also classified as being hard or soft. Hard fouling organisms include calcareous organisms such as barnacles, encrusting bryozoans, mollusks, polychaetes and other tube worms, and zebra mussels. Soft fouling organisms include non-calcareous organisms such as seaweed, hydroids, algae and biofilm "slime". Together, these organisms form a fouling community. Waste products from bacteria may include substances like sulfuric acid, which may corrode steel. In marine structures, corrosion may at least partly be attributed to biofouling, usually called microbial induced corrosion (MIC).

[0045] Biofilm formation may be reduced by using a higher potential in an ICCP like system, for example 0.95 V-1.1V. This may be called impressed current anti fouling (ICAF). When bacteria come into contact with a metallic surface that has been negatively charged at said higher potential, repulsion forces thus produced may reduce attachment of the bacteria onto the surface. Similar systems may aim at stopping fouling by dissolving Cu ions in the water. Various other systems are known to reduce biofouling. The book "Microbiologically Influenced Corrosion", by Javaherdashti, in particular chapter 9, pp 133-158, provides an overview of the various known systems to reduce MIC. Chapter 9.2.2 discusses ultraviolet radiation, in particular various shortcomings of UV treatment.

[0046] The following is noted in respect of anti-biofouling by using ultraviolet light as proposed. The light source may be chosen to specifically emit ultraviolet light of the c type, which is also known as UVC light, and even more specifically, light with a wavelength roughly between 220 nm and 300 nm. In practice the peak efficiency is achieved around 265 nm, with a fall-off towards higher and lower wavelengths. At 220 nm and at 300 nm, is has dropped to ~10% efficiency.

[0047] In the following, the present invention will be explained with reference to an application scenario in a monopile of a wind turbine, which is an example of a marine structure usually protected by ICCP. Wind turbines are often placed on monopiles. Corrosion due to microorganisms is usually called microbial corrosion or bacterial corrosion, bio-corrosion, microbiologically influenced corrosion, or microbial induced corrosion (MIC), which corrosion is caused or promoted by microorganisms, usually chemoautotrophs. The inside of the monopiles was assumed to be less vulnerable for such corrosion as the space is usually air-tight. It has been found that accelerated corrosion of surfaces protected by ICCP may be due to such microorganisms. The monopiles are an example of offshore marine constructions which may be affected. However, any steel or metal structure may be protected by the proposed system.

[0048] Fig. 1 shows an example of a system for enhancing corrosion protection of a protected surface. The Figure shows, in vertical intersection, the system 100 having a light emitting arrangement 20 in combination with a marine structure 110 which is partly immersed in a liquid 120 containing biofouling organisms, for example sea water. In the example the marine structure 110 is partly embedded in the soil 130, for example schematically indicating a monopile for carrying a wind turbine or a leg of an oil platform. The marine structure has a protected surface 30 which is electrically conductive and is protected against corrosion by impressed current cathodic protection, as further described above. For providing the cathodic protection the marine structure may be provided with an anode 112, while the steel parts of the structure constitute the cathode.

[0049] The light emitting arrangement 20 has a light source for emitting anti-fouling light 22. The light emitting arrangement is constructed to emit the anti-fouling light from the light source towards a zone of the protected surface 30. In the Figure, the zone has a part 35 located at a height of the liquid level, which level is commonly called the liquid line 31. The zone may have parts below, at and/or above the liquid line.

[0050] In the exemplary light emitting arrangement, the light source is arranged to emit at least part of the anti-fouling light directed to the part 35 of the zone just above the liquid line, while some of the anti-fouling light may be lighting some higher areas. The optical power of the light source is chosen to be at least sufficient to illuminate said part 35 near the liquid line at an intensity sufficient for anti-fouling. Using an appropriate light guiding and/or focusing arrangement to direct the light towards said part may reduce the required optical power of the light source. As such, light armatures providing a concentration of emitted light at an area to be illuminated are well-known.

[0051] The system 100 further has a detector 23 for generating level data indicative of the level of the liquid line, and a controller 21 for controlling the intensity of the anti-fouling light at the zone in dependence of the level data. For example, both the controller and the detector may be suspended from a central cable 40 also carrying the light emitting arrangement, as shown in the Figure. Alternatively, the detector and/or controller may be located elsewhere on the marine structure, and/or may be combined in a single unit.

[0052] The detector has circuitry to provide or generate the level data representing the liquid level. The detector may be constructed to detect the level of the liquid, and/or to receive level signals that enable deriving the liquid level. For example, such signals may be provided by an ICCP control system, or may be provided externally, e.g. data regarding tides acquired via internet or acquired by a separate measurement system for multiple marine structures like a field of wind turbines. The detector may have one or more sensors, and/or an interface to such sensors or other detectors or control circuitry to acquire the level signals representing the liquid level, or the liquid being at or above one or more predetermined thresholds. For example, the detector may have one or more liquid level sensors that detect the level with reference to a fixed point, e.g. using a distance measurement. A liquid sensor may directly detect the presence of liquid at the position where the sensor is mounted. By having one or more liquid sensors mounted at appropriate points or heights on the marine structure, the detector may be constructed to detect whether the level exceeds a predetermined threshold, or one or more of multiple thresholds at various heights. The detector may alternatively, or additionally, be arranged to detect that the light source is above or under water, e.g. by a sensor mounted near or one the light source. Also, the detector may include an absorption or transmission detector.

[0053] The controller is constructed to control the intensity of the anti-fouling light at the zone in dependence of the level data. In a practical embodiment, the controller may have electronic circuitry to directly control the light source based on an incoming signal from the detector. For example, the controller may switch on the light source, when the level data indicates that the liquid is below a fixed threshold. Also, the controller may have a state machine, or a microcontroller having an embedded program, to control the intensity of the anti-fouling light. The controller may be coupled to a light intensity detector at the zone, or near the light source. Also, the electrical power to the light source may be controlled or detected to control the intensity of the anti-fouling light. The controller may also control light source, the light emitting arrangement and/or other elements of the system like an adjuster for adjusting the position of the light source. For example, the light emitting arrangement be constructed to move the light source, and or mirrors or lenses, and the controller may control such elements so as to direct or focus the light emitted from the light source on specific parts of the zone. Also, the controller may be arranged to activate the light source for controlled periods, and/or adjust the amount of anti-fouling light at the zone, in dependence of the level data. Also, in dependence of the level data indicating that the liquid level is low, the anti-fouling light may be controlled to be more intense.

[0054] The controller may be arranged to control the light source in dependence of the liquid level falling below a predetermined threshold. If so, the light source may be switched on or the intensity of the anti-fouling light may be increased. The intensity of the light source may be adjusted by the controller so that the intensity of the anti-fouling light arriving on a zone is constant. Also, the controller may be arranged to control the light intensity to compensate for absorption, e.g. when the level data indicates that the light source is submerged in the liquid, or based on a measurement signal from a sensor detecting the absorption.

[0055] In the example as shown in Fig. 1, the light unit is positioned at a fixed, central position in an inner space 115 of the marine structure. So, the anti-fouling light may be emitted in a 360-degree range.

[0056] In practice, for prevention of fouling a protected surface should receive optical power of around 30 mW / m2. In air the absorption of UVC light is negligible, but in clean seawater it is about 4%/cm. This may lead to a different arrangement below the waterline, e.g. using multiple light sources close to the protected surface.

[0057] Assuming that a monopile has an inner space having a diameter of 7 m, above the waterline a low power lamp of a few watt / m could keep the surface free of bio films and the bacteria responsible for MIC. If only the area in the neighborhood of the waterline would need protection a 5 Watt TL lamp on a floater may be sufficient.

[0058] In an embodiment, the intensity on an area 35 just above the liquid line may be increased when the level is below a time-averaged level of the liquid line. This means increased when compared to an intensity of the anti-fouling light of a light emitting arrangement that is not adjusted to variations of the level. For example, the intensity and/or position of the light source can be adjusted by the controller to control the intensity of the anti-fouling light at the protected surface near the liquid line to be substantially constant. It has been noted that part of the zone just above the liquid line, which is above the liquid line when the level is below a time-averaged level of the liquid line, may be prone to more intense fouling while it is still wet.

[0059] In an embodiment, the controller is arranged to control the power of the anti-fouling light as emitted in dependence of the level data for controlling the intensity of the anti-fouling light at the zone. Effectively, the light source may remain at a fixed height with respect to the marine structure, while the intensity is adjusted to follow vertical variations of the liquid level. The amount of power required for the light source is reduced when the liquid level is high, while more power is required when the level is low. The change may be made proportional to the size of the part 35 of the zone that is exposed due to the liquid level going down, taking into account the distance to said area. For example, the controller may be arranged to calculate the distance from the light source to the part 35 to be illuminated. The actual distance can be easily derived from the actual level data and a one-time distance measurement at a known liquid level during installation, by design of the system and/or by installation at a predefined height. Based on the actual distance the amount of anti-fouling light is calculated, and the corresponding power can be applied to the light source by the controller. Also, a feedback may be added to the controller, such as a light sensor, so as to enable to control the light source to emit a required intensity. Such a feedback loop may also compensate for aging and/or fouling of the light source itself. Optionally, one or more light sensors may be located on or near the protected surface, e.g. just above the highest liquid line level and/or at some lower levels, so as to sense the actual intensity of the anti-fouling light at the protected surface. Corresponding sensor signals may then be coupled to the controller to control the intensity in a feedback loop.

[0060] In an embodiment for countering the more intense fouling of a part of the protected surface near the liquid line, the controller may increase the intensity of the light source further when such part can be illuminated due to the level of the liquid going down or being low. Then the controller controls the intensity of the anti-fouling light at the protected surface during a low liquid level to be substantially higher than at a high liquid level, for example two or three times the regular intensity.

[0061] Optionally, the system comprises an adjuster to move the light source vertically and/or in a direction parallel to the surface of the liquid. When appropriately controlling such movements, a less powerful light unit may be used. Also, the light unit, or the light emitted by such unit, may be made to scan along the protected surface and to light only part of the surface at any given time, while covering the full surface during said scanning movement.

[0062] Fig. 2 shows an example of a system for enhancing corrosion protection having a height adjuster. The Figure shows, in vertical intersection, the system 101, which is, like in Fig. 1, mounted in a marine structure 110 which is in contact with the liquid 120. The system 101 has a light emitting arrangement 20 comprising a light source 20 for emitting anti-fouling light 22. The light emitting arrangement may be arranged to especially illuminate, by the anti-fouling light, the protected surface 30 at a zone near the liquid line 31.

[0063] In the embodiment, the system has an adjuster 24 arranged to adjust the height of the light source with respect to the marine structure. For example, the height adjuster may have a motor to adjust the length of a suspension cable of the light emitting arrangement. Alternatively, the height adjuster may have a rod provided with a screw-threat or worm to is rotated by a motor, or a linear displacement unit activated by a stepper motor, coupled to the light source so as to move the light source up and down. The controller is arranged to control the height in dependence of the level data for controlling the intensity of the anti-fouling light at the zone. Effectively, the light source may follow vertical variations of the liquid level, e.g. due to tides, so the device is kept at a required vertical position near that part of the protected surface that is wet by intermittently being immersed. Instead of, or in addition to, adjusting the height of the light source itself, the adjuster may adjust distribution of the light towards the protected surface. For example, the adjustable distribution of light may be achieved by movable mirrors or lenses.

[0064] Optionally, the light emitting arrangement has a guidance element 40 for coupling to the marine structure, for example a central cable or rod. The controller may be arranged to have the light emitting arrangement move up and down via the guidance element in dependence of the level data. For example, the light emitting arrangement may be movably attached to the central cable, while the controller is coupled to a motor in the light emitting arrangement to move the light emitting arrangement up and down along the cable. The controller may also be mounted on the light emitting arrangement and so itself also move up and down. Effectively the height of the light emitting arrangement is now controlled with reference to the marine structure via the guidance element. In the example, the light emitting arrangement is shaped to movably fit within an inner space 115 of the marine structure, while the protected surface 30 is formed by the inner surface of walls of the inner space. For example, in a monopile there may be a round inner space. In use, the inner surface of the marine structure receives the anti-fouling light at the zone, e.g. near the liquid line, where the impressed current cathodic protection is less effective.

[0065] The marine structure has a protected surface 30 which is electrically conductive and is protected against corrosion by impressed current cathodic protection, as further described above. The system may have an electrode 113 coupled to the guidance element below the liquid line. The system may further have an impressed current cathodic protection power source (not shown). The power source is electrically connected to the guidance element and the conductive walls of the marine structure to provide the electric current between the protected surface and the electrode 113. The electrode is mounted on the guidance element (instead of mounting the electrode in an isolated way on the marine structure itself like in Fig. 1). The guidance element 40 is isolated from the marine structure to enable a voltage between the electrode and the protected surface.

[0066] Fig. 3 shows schematically an electrical circuit of a protection system. The system provides protection against corrosion according to the ICCP system as described above. Only the electrical elements of the system are shown in combination with a metal part 111 of the marine structure connected to the protected surface 30. The impressed current cathodic protection is achieved by providing an ICCP electric current between the protected surface and an electrode immersed in the liquid. The Figure shows an ICCP power source 118 coupled to the metal part 111 of the marine structure and an electrode 114 to be immersed in the liquid for providing the ICCP electric current between the protected surface 30 and the electrode 114.

[0067] The electrical circuit shows the controller 21 which is electrically connected to a light source 25 in the light emitting arrangement and the detector 23 that generates level data indicative of the level 32 of the liquid. As indicated by arrow 119 the controller is electrically coupled to the ICCP power source 118, according to one or more of the following options.

[0068] Optionally the controller and the light source are powered by the ICCP power source 118, so the same power source is used to provide power to both the ICCP protection and for the anti-fouling light source.

[0069] Optionally, the controller is arranged to provide, via the ICCP power source, the electric current for the ICCP in dependence of the level data for adjusting the electric current to the part of the protected surface that is in contact with the liquid. The ICCP control may be arranged to result in a predefined voltage between the protected surface and the liquid. The controller may be arranged to control the strength of the electric current in dependence of the level data for adjusting the electric current to the part of the protected surface that is in contact with the liquid. The amount of current required for the impressed current cathodic protection is increased when the liquid level is high, as a larger surface is now in conductive contact with the liquid. The required increase in the ICCP current due to a level increase may be preset in the controller, e.g. during installation. For example, the amount of current per square meter may be kept substantially constant. Similarly, less current is required when the level is low. Advantageously the total required power is reduced, compared to an uncontrolled system where current must be high at all times.

[0070] Fig. 4 shows schematically a further example of an electrical circuit of a protection system having a power arrangement. The Figure shows the same elements as Fig. 3. The system may additionally be connected to the ICCP power source as shown in Fig. 3, or the power and control signals may be transferred via an ICCP power connection 126. In the example, the system comprises a power arrangement 26 arranged to power the light source and/or the controller from the ICCP electric current. Thereto the electrode 114 is now connected to the ICCP power source via the power connection 126 and the power arrangement 26. For example, the power arrangement may have a power supply circuit connected in series with ICCP current to derive power from the ICCP current, or connected in parallel between the electrode and the marine structure to derive power from the ICCP voltage. Effectively, the power arrangement 26 achieves that the power source providing the electric current for the impressed current cathodic protection is shared for also providing the power to the light source. In an embodiment, the controller is also arranged to control the ICCP power in dependence of the level data from the detector 23, as described above with Fig. 3. Optionally, at a low liquid level, the amount of power for the light source may be increased while the amount of power for the impressed current cathodic protection is decreased. Due to the combined control, the total required power capacity of the ICCP power source 118 is reduced compared to a system that has the electric power and/or the light intensity at a high level independent of the liquid level.

[0071] Fig. 5 shows an example of a system for enhancing corrosion protection having a rotator. The Figure shows the system 104, similar to Fig. 1, in combination with a marine structure 110, and differing with respect to the light emitting arrangement. The light emitting arrangement is arranged to rotate as indicated by an arrow. For example, the device may rotate by rotating a central cable 42 on which the device is suspended by an electric motor (not shown). Also at least part of the light arrangement may rotate, for example by rotating a part of the light emitting arrangement carrying the light unit or light units. The turns don't need to be fast; once in a few hours is fine. The mechanism to rotate may also be used in the other embodiments of the device.

[0072] In the example the light emitting arrangement 44 has a platform or plate that is suspended from a central cable 42 and further suspension cables 43. The platform is part of the light emitting arrangement and carries a light source 28. The central vertical cable may cooperate with a central eye in the device to constitute a guidance element, while the light emitting arrangement moves up and down with the liquid level. The cable may be fixed below the water line or may have a weight pending for keeping the cable straight.

[0073] The controller 21 and the light source 28 may be mounted on the plate. A detector 29 for detecting the liquid level may be mounted on the marine structure, or on the plate. The intensity of the light source 28 is controlled by the controller 21 based on the detected level as described above. The intensity of the light source may be increased when the level is becoming lower so as to more intensely illuminate the surface that is still wet just above the liquid line.

[0074] Optionally, the light emitting arrangement 44 has a float 50 for floating the device at the surface of the liquid. The central cable 42 and the suspension cables 43 may be omitted. During floating the device may be kept within a distance from the protected surface, for example, by a few bumpers, buffers or fenders at the outer boundary of the device at the device liquid line.

[0075] The cable 42 may be suspended from a fixed point (not shown) of the marine structure. The cable may be flexible, or be guided via a pulley using a counterweight, to adapt to a varying level of the liquid and allow the light emitting arrangement to keep floating on the liquid while being positioned at a required distance from the protected surface. A detector 29 may be coupled to the cable 42 for detecting the level of the liquid. For example, the extended length of the cable may be detected near said pulley, or the tension on the flexible cable, as being indicative of the level of the liquid.

[0076] The light unit may be mounted in a central position having a beam directed to a part of the protected surface above the liquid line, or one or more light units may be mounted close to the protected surface. The beam, or the one or more light sources which are arranged on, or near the outer boundary of, the light emitting arrangement may be moved along the protected surface due to rotation of the light emitting arrangement. The plate and/or the light unit(s) may be made to rotate, e.g. by a rotator motor. Due to the rotation, shadows cast by protruding elements of the marine structure may vary in shape and location, so that all of the zone is illuminated at some time during the rotational movement.

[0077] The light emitting arrangement may have a rotator element 51 for, in use, rotating the light emitting arrangement driven by variations of the level of the liquid. In a practical embodiment, the rotator element may be a propeller or screw shaped element, in use, being immersed in the liquid.

[0078] The rotator element may be a worm type interface to a fixed guidance element, such as the cable 42 or a central rod. Effectively the light emitting arrangement follows the level of the liquid line, while rotating via the worm type interface. For example, a platform can be made to float while coupled rotatable to a cork screw stick fixed to the marine structure. Due to tides the platform moves up and down while the cork screw is kept at the same level. Hence the platform is forced to rotate by the cork screw stick. Also, a floatation device may have a cork screw stick pointing upwards coupled to a rotatable platform or illumination unit. Due to tides the floatation device moves up and down while the platform is kept at the same level. Hence the illumination unit is forced to rotate by the cork screw stick moving upwards through the platform, by the tides. Care has to be taken though to make sure the corkscrew itself does not rotate, but instead the 'cork' (i.e. the platform) rotates.

[0079] The light emitting arrangement 44 may have at least one additional light unit 27 mounted under the liquid line, e.g. pending below the waterline. The light emitting arrangement is arranged to have the light unit 27 emit the anti-fouling light from a very short distance towards the protected surface taking into account the absorption of the liquid, so that a substantial part of the anti-fouling light reaches a submerged part of the protected surface 36, 36' extending below the liquid line.

[0080] Due to the absorption of the liquid the light units need to be closer to the wall to prevent the forming of biofilms or other bio fouling. So, the distance keeper is arranged to keep the submerged light unit within a predetermined distance of the submerged part, the predetermined distance and optical power of the light unit being determined in view of absorption of the anti-fouling light by the liquid. It can be calculated that e.g. a following configuration would be sufficient to prevent bio fouling using (mercury gas) lamps powered and kept within a predetermined distance. The estimated power is given for an area 36 having a height of 1 meter (i.e. amount of power per altimeter). For a monopile of diameter D = 8 m, the surface for one altimeter is

π * D * 1 meter = 25 m2. At a required intensity of 30 mW/m2 UV at the surface, the total UV light power = 25 * 30 mW/m2 UV = 750 mW UV. The corresponding electrical power is (assuming about 30% efficiency) 750 mW / 30% = about 2.5 W. At a predefined distance of 17 cm and a transparency of 85% / cm the remaining intensity is 6%, so about 2.5/6% = 35 W total required average power. The light energy emitted by a configuration of about 10 static lamps may effectively arrive only partly at the protected surface due to losses of distribution and the lamps being static, so in practice more power will be needed, e.g. 165 W.

[0081] Optionally, the control unit 21 is arranged to determine one or more of the following parameters: the distance to the protected surface, the optical power of the light unit, the electrical power of the light unit, the absorption of the anti-fouling light by the liquid, the amount of biofouling actually occurring, etc. The parameters may be pre-set and/or may be adapted dynamically. The control unit may include various sensors for measuring respective parameters, and/or may be connected via a network to receive one or more parameters. For example, the actual optical power emitting from the light source reaching the protected surface may be measured via an UV sensor near the surface. Such parameters may be updated regularly, e.g. according to a programmed schedule, by an operator or automatically via a remote connection to the control unit. Based on the parameters the optical or electrical power of the light source may be controlled, and/or movement of the light source may be adapted by the control unit. Also, the control unit may generate warnings and/or error messages, e.g. when a light source fails.

[0082] It will be clear to a person skilled in the art that the scope of the invention is not limited to the examples discussed in the foregoing, but that several amendments and modifications thereof are possible. While the invention has been illustrated and described in detail in the figures and the description, the figures and description are to be considered illustrative or exemplary only, and not restrictive. The invention is not limited to the disclosed embodiments. The drawings are schematic, wherein details that are not required for understanding the invention may have been omitted, and not necessarily to scale.

[0083] Variations to the disclosed embodiments can be understood and effected by a person skilled in the art in practicing the claimed invention, from a study of the figures, the description and the attached claims. For example, the various embodiments of the light emitting arrangement may be combined to constitute a device that has multiple light sources.

[0084] In the claims, the word "comprising" does not exclude other steps or elements, and the indefinite article "a" or "an" does not exclude a plurality. The term "comprise" as used in this text will be understood by a person skilled in the art as covering the term "consist of'. Hence, the term "comprise" may in respect of an embodiment mean "consist of', but may in another embodiment mean "contain/include at least the defined species and optionally one or more other species". Any reference signs in the claims should not be construed as limiting the scope of the invention.

[0085] Elements and aspects discussed for or in relation with a particular embodiment may be suitably combined with elements and aspects of other embodiments, unless explicitly stated otherwise. Thus, the mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

[0086] In a general sense, it is a basic function of the system and the light emitting arrangement according to the invention to keep a protected surface free from biofouling. Hence, the invention is applicable in all situations involving a fouling risk, which are situations in which the protected surface is intended to be immersed, at least during a part of the lifetime thereof, in a liquid containing biofouling organisms. Seawater is a well-known example of such a liquid. So, a marine structure may have a surface protected by the above described light emitting arrangement. A method is provided for enhancing corrosion protection of a protected surface of a marine structure in contract with a liquid containing biofouling organisms using a system as described above. The method involves providing impressed current cathodic protection, for example by providing current from a DC power source via the protected surface being electrically conductive. The method further involves having the system illuminate the protected surface and powering the light source to emit the anti-fouling light, while controlling the intensity based on detecting the liquid level.

[0087] According to an aspect of the invention, use of the above system and light emitting arrangement is foreseen, in particular use installed on a float near a protected surface of a marine structure for enhancing corrosion protection of the surface when partly immersed in a liquid containing biofouling organisms. The use requires the light emitting arrangement to be powered by an electrical power source. Other examples of the protected surface include surfaces of subsea off-shore equipment, interior walls of water reservoirs like ballast tanks of vessels, and surfaces of filter systems in desalination plants.

[0088] According to an aspect of the invention, the controller is arranged to operate the light source in dependence of the liquid level falling below a predefined threshold. The light source may, for instance, be switched on, when the water level falls below a predetermined level.

[0089] According to an aspect of the invention, the controller may be arranged to have the floater device irradiate the protected surface around the time the liquid level is below a predefined threshold.

[0090] According to an aspect of the invention, wherein the light emitting arrangement comprises a rotator element for, in use, rotating the light emitting arrangement with respect to the marine structure due to variations of the level of the liquid.

[0091] According to a further aspect of the invention the rotator element comprises a propeller or screw shaped element for, in use, being immersed in the liquid at a stationary height.

[0092] According to a further aspect of the invention the rotator element comprises a worm type interface to a guidance element that is at a stationary height.

[0093] Summarizing, a system is provided for protecting enhancing corrosion protection of a protected surface of a marine structure in contact with a liquid containing biofouling organisms. The protected surface is electrically conductive and being protected against corrosion by impressed current cathodic protection. The system has a light emitting arrangement having a light source for emitting anti-fouling light to illuminate a zone of the protected surface. A detector generates level data indicative of the level of the liquid line, and a controller controls the intensity of the anti-fouling light at the zone in dependence of the level data. The intensity may be increased when the level is below a time-averaged level of the liquid line.

Claims

1. A system for enhancing corrosion protection of a protected surface (30) of a marine structure (110) in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive and being protected against corrosion by impressed current cathodic protection (ICCP),
the system (100,101,104) comprising
a light emitting arrangement (20,44) comprising a light source (25,28) for emitting anti-fouling light (22), the light emitting arrangement being arranged to illuminate, by the anti-fouling light, a zone of the protected surface (30),
a detector (23,29) for generating level data indicative of the level of the liquid when the marine structure is partly immersed in the liquid, and
a controller (21) for controlling the intensity of the anti-fouling light at the zone in dependence of the level data.

2. System as claimed in claim 1, wherein the system comprises an adjuster (24) arranged to adjust the position of the light source, and the controller (21) is arranged to be coupled to the adjuster and to control the intensity of the anti-fouling light at the zone by adjusting the position in dependence of the level data.

3. System as claimed in claim 1 or 2, wherein the controller (21) is arranged to control the power of the anti-fouling light as emitted in dependence of the level data for controlling the intensity of the anti-fouling light at the zone.

4. System as claimed in any of the preceding claims, wherein system comprises a guidance element (40,42) for coupling the light emitting arrangement to the marine structure and arranged to have the light emitting arrangement move via the guidance element in dependence of the level data.

5. System as claimed in claim 4, wherein the light emitting arrangement is shaped to movably fit within an inner space (115) of the marine structure, the protected surface being formed by at least part of the inner surface of walls of the inner space, and the guidance element is a cable (42).

6. System as claimed in claim 4 or 5, wherein the system comprises an electrode (113) to be coupled to the guidance element and to be submerged in the liquid, and the impressed current cathodic protection is arranged to provide an electric current between the electrode and the protected surface.

7. System as claimed in any of the preceding claims, wherein the light emitting arrangement (44) comprises a float (50) for floating the light emitting arrangement relative to the zone.

8. System as claimed in any of the preceding claims, wherein the light emitting arrangement (44) comprises a rotator element (51) for rotating the light emitting arrangement with respect to the marine structure due to variations of the level of the liquid.

9. System as claimed in any of the preceding claims, wherein the impressed current cathodic protection is arranged to provide an electric current between the protected surface and an electrode (113) submerged in the liquid, and the system comprises a power arrangement (26) arranged to power the light source from the electric current.

10. System as claimed in any of the preceding claims, wherein the light source is arranged to be mounted so that it becomes exposed when the liquid level is below a predefined level, the detector is arranged to assess whether or not the light source has become exposed and the controller is arranged to operate the light source correspondingly.

11. System as claimed in any of the preceding claims, wherein the light source is arranged to be at a distance above the liquid to emit at least a part of the anti-fouling light at an angle towards the surface of the liquid so that the part of the anti-fouling light reaches a submerged part of the zone and the controller is arranged to operate the light source to emit the anti-fouling light when the liquid level is below a predefined level.

12. System as claimed in any of the preceding claims, wherein the controller (21) is arranged to control the impressed current cathodic protection, and/or the controller (21) is arranged to control the intensity of the anti-fouling light in dependence of the impressed current cathodic protection.

13. System as claimed in any of the preceding claims, wherein the system comprises an impressed current unit for providing the impressed current cathodic protection (ICCP) of the protected surface.

14. A marine structure (110), especially a support structure for a sea-based wind turbine, having a protected surface (30) arranged to beelectrically conductive to be protected against corrosion by impressed current cathodic protection (ICCP) when in contact with a liquid containing biofouling organisms, the marine

structure comprising the system (100, 101,104) as claimed in any of the preceding claims.

15. Method of enhancing corrosion protection of a protected surface of a marine structure in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive, the method comprising
providing impressed current cathodic protection (ICCP) via the protected surface,
illuminating, by anti-fouling light from a light emitting arrangement (20,44), a zone of the protected surface (30),
generating level data indicative of the level of the liquid when the marine structure is partly immersed in the liquid, and
controlling the intensity of the anti-fouling light at the zone in dependence of the level data.

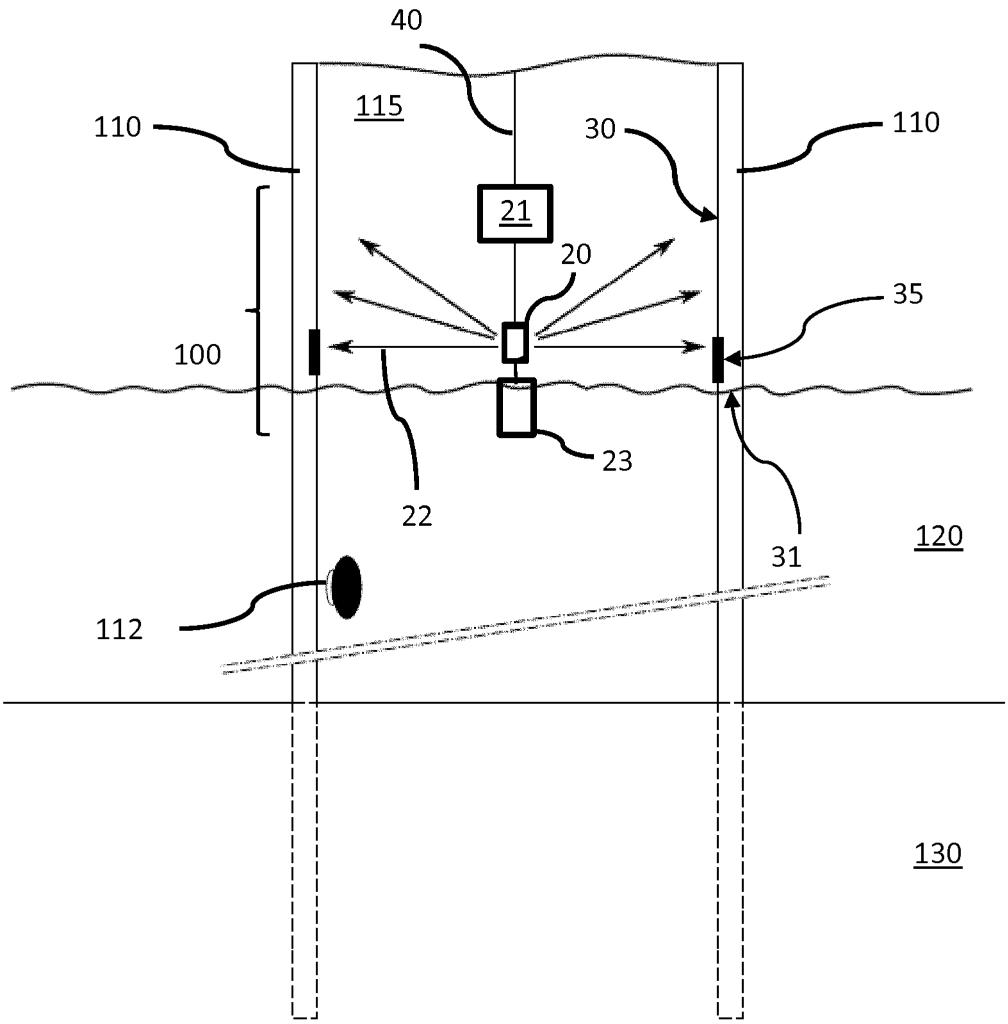

FIG. 1

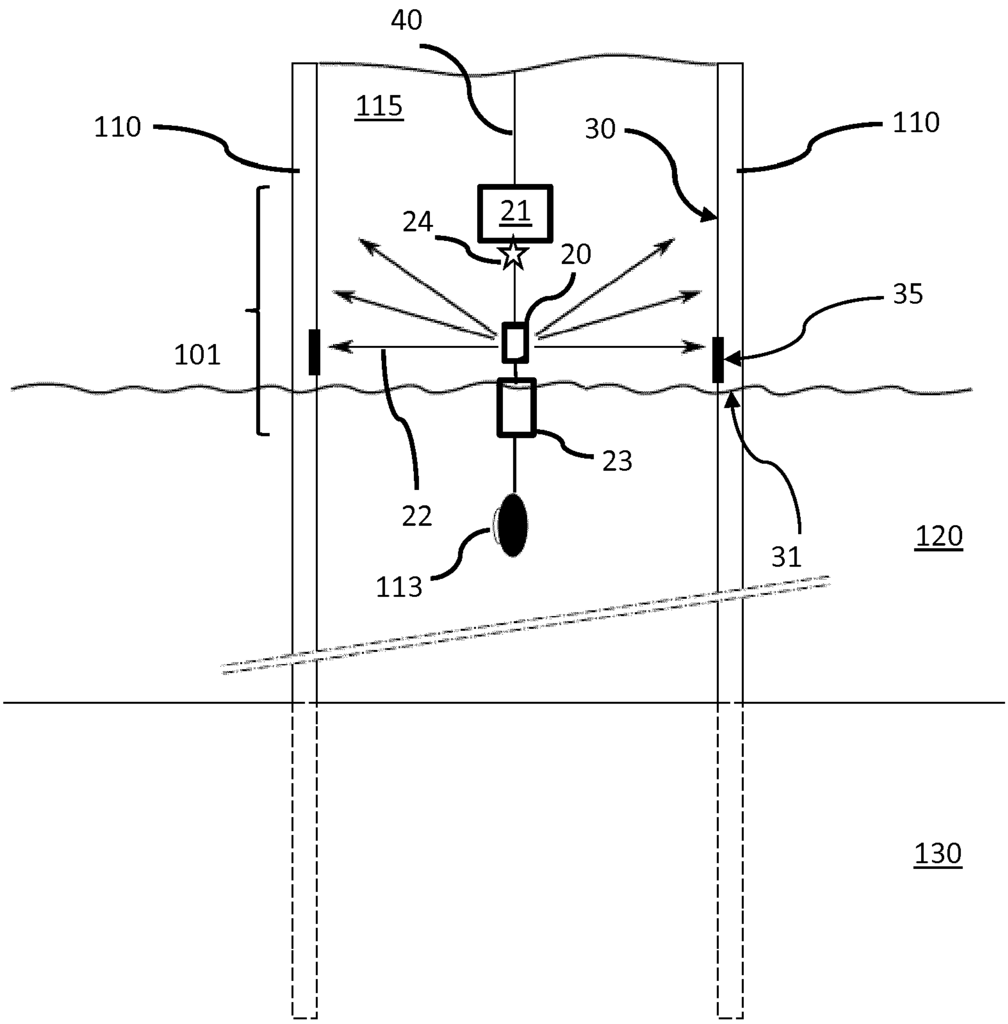

FIG. 2

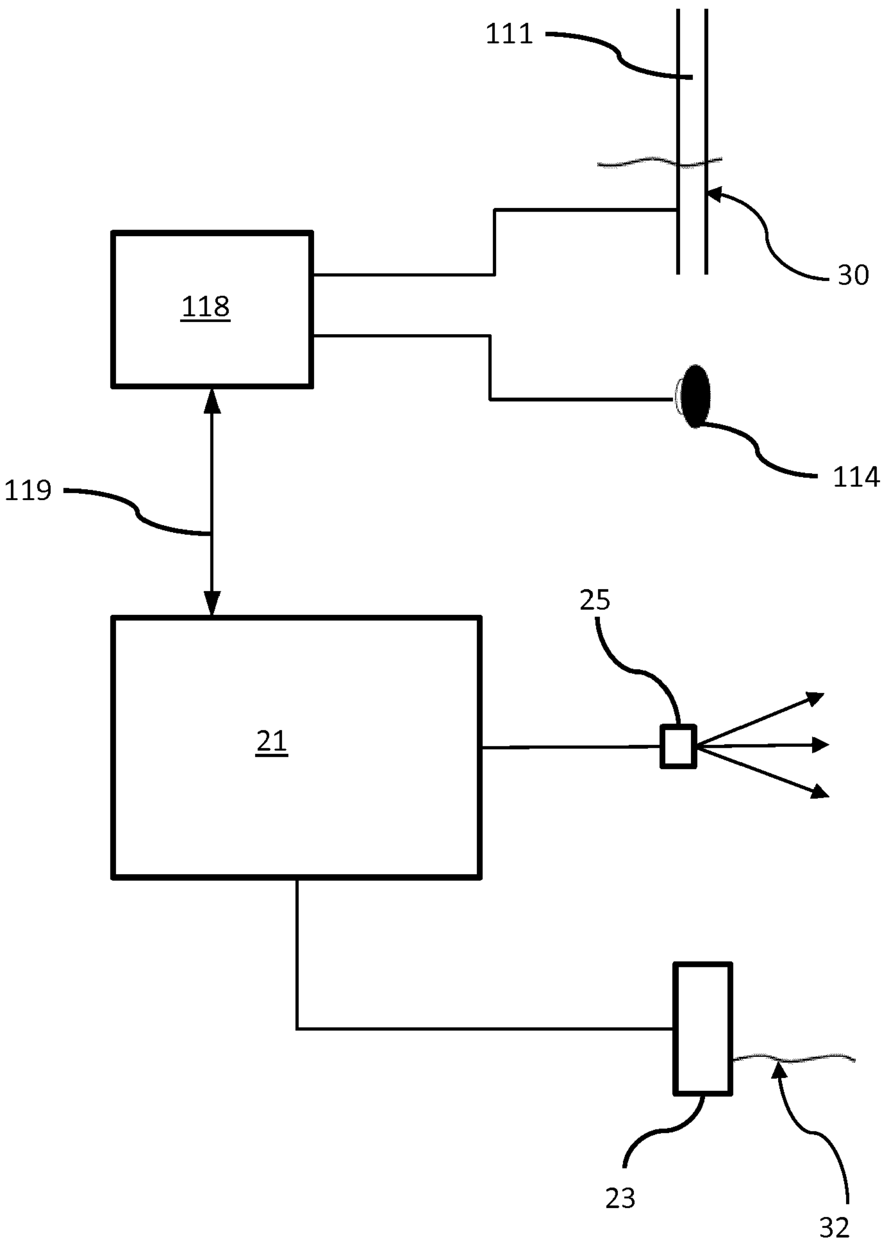

FIG. 3

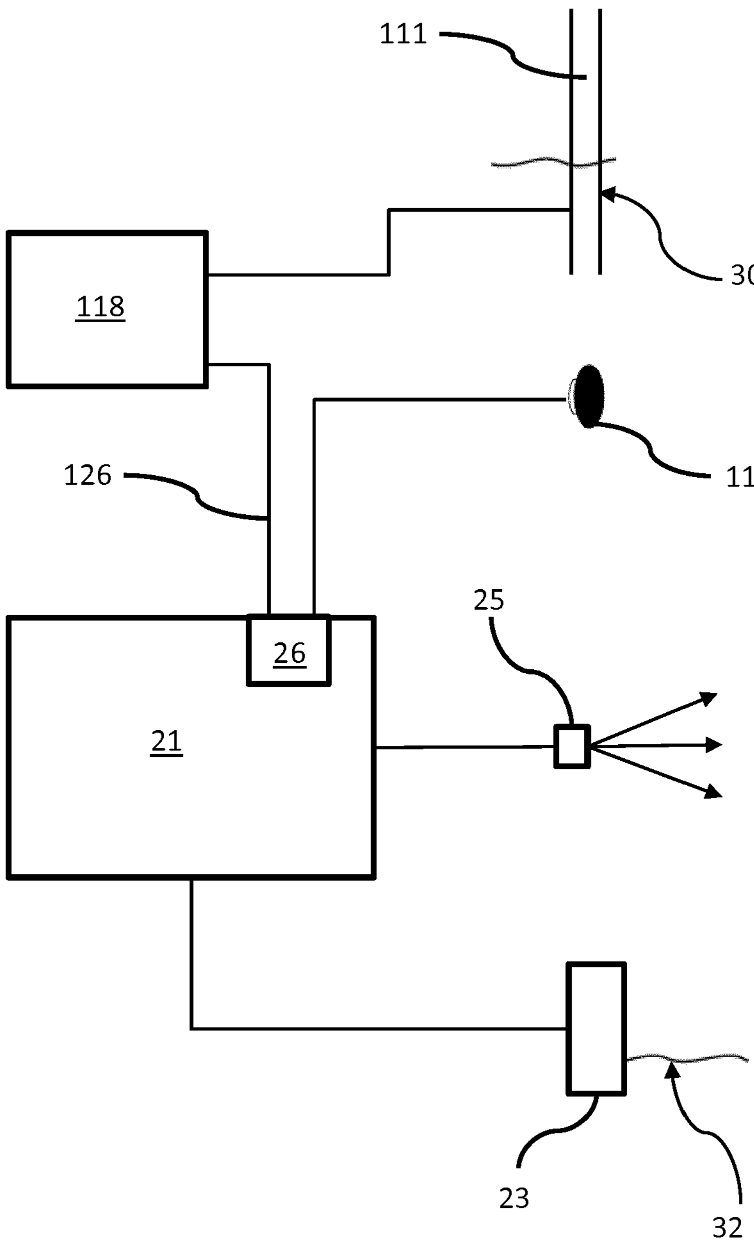

FIG. 4

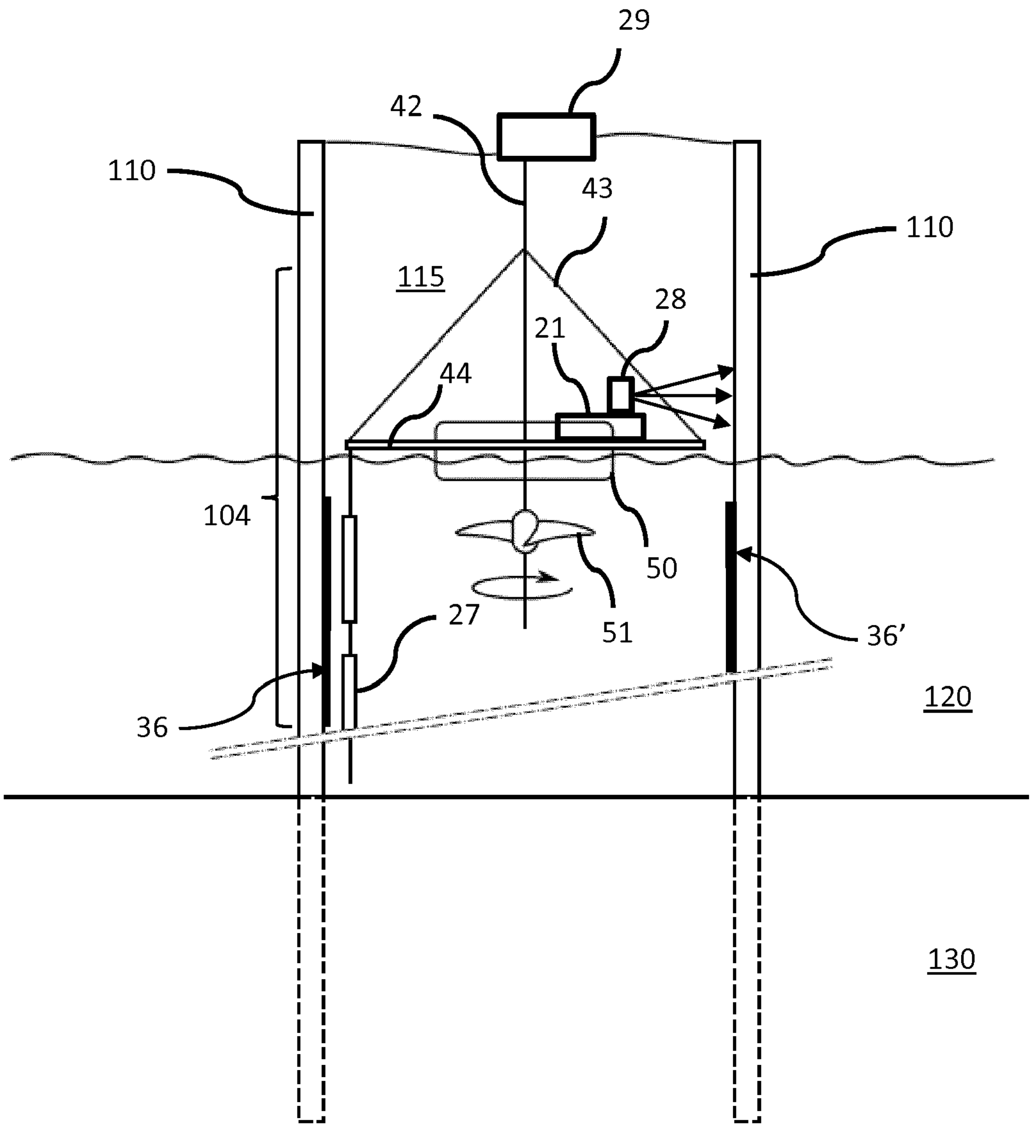

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 17 19 3084

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	WO 2016/000980 A1 (KONINK PHILIPS NV) 7 January 2016 (2016-01-07) * page 21, line 1 - page 21, paragraph 9 * * page 29, line 4 - page 36, line 13; figures 2, 5, 6 * * page 3, line 20 - page 3, line 33 * -----	1-4,7, 9-15 5,6,8	INV. H02J50/05 B08B17/02 B63B59/04 C23F13/02 C23F13/04 E02B17/00 C23F13/12
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TECHNICAL FIELDS SEARCHED (IPC)

H02J
B08B
B63B
C23F
E02B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	26 February 2018	Zuurveld, Gerben

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 19 3084

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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26-02-2018

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REFERENCES CITED IN THE DESCRIPTION

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