

SUBSEA SYSTEM COMPRISING A CRAWLER

FIELD OF THE INVENTION

The invention concerns a subsea system, and more particularly a subsea system comprising a crawler.

5 BACKGROUND OF THE INVENTION

It is in the oil industry a need to reduce complexity of installed production equipment and thereby improve the reliability of the system whilst reducing cost and weight. It is also a need to provide efficient and effective means to remotely maintain, improve reliability of, and increase commonality across all subsea
10 infrastructures of varying sizes and complexity, in all regions. There is also a need for providing a system for sensing and actuation in subsea production systems that is cost efficient and not too complex, and at the same time provides increased reliability of subsea production control systems. This is also relevant in remote and difficult-to-reach locations, such as the arctic.

15 One possible way of providing sensing or actuation is to provide equipment with fixed sensors/actuators and signal/control lines to a control unit possibly subsea with an umbilical to topside or alternatively a control unit topside. Another type of prior art solutions includes projects such as Saab SeaEye, and studies by companies like International Submarine Engineering, Lockheed Martin
20 and Cybernetix. Most of these studies include the use of technology including AUVs (Autonomous Underwater Vehicle) intended to provide primarily inspection-based services. The operational envelopes of the AUVs are limited by battery technology and the lack of technology in relation to high bandwidth communication through water. The "Swimmer" concept by Cybernetix provides
25 some level of intervention capability, possibly allowing a resident system to utilize field-provided power and communications infrastructure. However, the concept does not address the need for communicating with a wide range of sensors in the subsea infrastructure, as it needs a large vessel for deployment of the vehicle. In addition, it has not been designed to effectively maintain the subsea
30 hardware.

Another prior art solution is to use standard known ROV systems which can perform a wide variety of tasks. Using manipulators and various equipment, including hydraulic torque tools, ROV operators regularly perform tasks including valve operation, visual inspections, corrosion protection (CP) readings, hot stab

operations, and assistance with module replacements such as e.g. connection of running tools, or lift lines to subsea control modules (SCM) or other modules.

Oil companies desire an alternative to the ROV/AUV-based systems as vessels must be hired for extended periods of time in most cases, incurring
5 significant expense. Additionally, for fields that are inaccessible by typical vessels for limited or longer time periods during a year, e.g. the arctic, ROV intervention will not be possible. These known systems are neither addressing the need of reduced complexity of installed production equipment.

An object of the present invention is to reduce complexity of installed
10 production equipment, and thereby also improve the reliability of the system. Another aim is to reduce cost and weight of the installed production equipment. Another objective is to reduce the cost and maintenance difficulties, as well as increasing the capabilities of subsea production control systems.

Yet another objective is to reduce the complexity of sensing and actuation
15 in subsea production systems.

Yet another objective is to provide a system where some of the difficulties with known systems are alleviated or reduced.

SUMMARY OF THE INVENTION

The present applicant has devised and embodied a solution for limiting, or
20 even eliminating, the needs of complex functionality in the subsea system. The system according to the invention may significantly reduce the installed infrastructure whilst enabling shared actuation and repair/replacement functionality resident on the subsea structure. The present invention also provides a system for sensing and control and or actuation in a subsea
25 production system, and at the same time increase the reliability of subsea production control systems and the commonality of components used in them.

The invention is set forth and characterized in the independent claim, while the dependent claims describe other characteristics of the invention.

The subsea system according to the invention may solve a number of
30 tasks on a conventional subsea installation plant; including actuation of valves, perform surveillance and or inspections, including noise, vibration and visually inspection by using e.g. a camera, and/or function as the control unit for a number of different subsea applications either for a limited or extended time due to malfunction in the main control system, or due to the need of performing
35 other/additional tasks.

The invention relates to a subsea system comprising: a subsea installation having at least one negotiable surface and at least one recharge station, at least one crawler freely movable on the negotiable surface of the subsea installation, and wherein each crawler has rechargeable means for charging by at least the
5 recharge station.

The one negotiable surface may be a planar or to some extent curved surface, provided that the crawler has an attachment system for being in contact with the surface. The surface may be an inside or outside surface, possibly oriented in any direction, including vertical and horizontal. The surface may be
10 called substantially planar. The surface may also comprise different kinds of sections, some planar and some transition sections with curvature forming a common substantially planar surface. The negotiable surface has to be of a kind whereon the crawler can freely move and keep contact with the surface. Dependent on the crawler, the surface may have larger or smaller curvature of
15 the surface whereon the crawler should move.

In an embodiment, the subsea installation may further comprise at least one umbilical termination head, the umbilical termination head may be connected to at least one power source and may have wireless communication means, wherein the at least one recharge station may form part of the umbilical
20 termination head.

In an embodiment of the subsea system, the at least one crawler may have communication functions and rechargeable elements for communication with the wireless communication means and the recharge station on the umbilical termination head, respectively. The communication functions may also be
25 adapted to communication with other components in the subsea structure. These other component may also be other crawlers in the subsea system. The communication functions may also be used for communication with system temporary positioned subsea, as ROVs, intervention systems etc. These communication functions may be wireless communication and or plug in systems
30 for communication. By having the crawler being able to communicate with several elements gives the possibility for the crawler to move around and pick up information from several units, transfer these to a central unit for communication with operator, and also transfer communication back to the several units.

According to another aspect at least one crawler may comprise a control
35 module pack, adaptable to control subsea systems the crawler attaches to. With

such a system the subsea installation needs only a limited number of control units, as the crawler with the control module pack may move around between different elements that needs to be controlled and or operated at different times. The control module pack may also be a substitute for having a backup system on
5 each element in case failure in a fixed control unit. By having a number of crawlers with a control unit pack, these may, when there is a failure, move to the given place and connect and thereby be the backup until a scheduled maintenance is performed.

At least one crawler in the subsea system may further comprise operating
10 devices for manipulating subsea components, e.g. such as opening and closing manual valves and or actuating a valve or other element. This gives that the valve/element structure in a subsea system may be less complex, as one may reduce the numbers of fixed actuators and possibly also backup systems for these actuators, since the crawlers may act as the backup system.

15 In an aspect, the at least one crawler may have sticking means. The sticking means are sticking elements connecting and keeping the crawler connected to the negotiable surface. Such means may be magnets, a tape system, suction cups or similar making it possible to move the crawler in all directions along the surface of any subsea structure having substantially plane
20 surfaces, i.e. the crawler is movable horizontally on a top surface, upside-down under a surface, along a side wall i.e. vertically etc.

In an embodiment the at least one crawler may have propulsion means. The sticking means may in one embodiment be arranged on the propulsion means, e.g. the wheels, belts etc., or as part of the crawler body.

25 In an aspect, the power source may be a subsea turbine, surface equipment through an umbilical, thermocouple, a battery pack etc. The battery pack may then at intervals be recharged or replaced. Another option is to have the battery pack continuously charged by a thermocouples or other element providing a small charge per time unit.

30 In one embodiment, the operating devices may comprise an extendable torque tool for manipulating e.g. valves.

In an aspect of the subsea system, the at least one crawler may further comprise navigation cameras. In another embodiment the crawler may have other or additional navigation means different from navigation cameras, such as
35 sonar, laser positioning, swag points, tags, and acoustic. Alternatively the

crawlers may be (pre)-programmed to follow a specific safe route avoiding obstacles, e.g. a pathway. The crawler may also be provided with a positioning device, providing signal to its position and receiving corrections if moved outside safe routes. In an aspect, the propulsion means may comprise casters or
5 wheels. Alternatively it may be propellers moving the crawler forward, while the sticking means are wheels or other elements keeping the crawler attached to the surface.

In an embodiment, the recharge station and the rechargeable means are inductive. This may be resonant inductive couplings which are connected. The
10 recharging may be by plug in systems and or it may be wireless.

In an embodiment of the subsea system according the invention, the umbilical termination head may be provided with a guiding arrangement for cooperation with an extending portion on the crawler for charging. The guiding arrangement may also comprise the recharging system.

15 According to another aspect of the invention the system may also comprise at least one crawler comprising an umbilical connected to the subsea structure. This may be used in the case the crawler should be able to operate several elements closely positioned.

In a preferred embodiment, the surfaces of the subsea structure are
20 negotiable or substantially planar, such that the crawler may move freely, without obstructions, on the entire surface of the subsea structure or dedicated pathways.

In one embodiment, the solution according to the present invention renders possible to use less costly manual valves. The valves used may be
25 valves operable by ROVs, rendering it unnecessary to design new valves. Alternatively, the valves may be made less complicated as crawlers are more stable relative the valves than an ROV (only movable in 2D in comparison with 3D). In any design, the crawler may be equipped with a torque tool or a hydraulic actuation tool making the crawler able to manipulate valves and/or
30 hydraulic actuators on the subsea structure.

According to an aspect of the invention the interfaces of elements to be operated by a crawler, for instance the valves, may in one embodiment be arranged as recesses below the surface of the subsea structure such as to avoid that the crawlers are obstructed by these interfaces. In this embodiment, the
35 crawlers made for manipulating valves, may have a torque tool that is retracted

above the surface of the subsea structure when in a non-operating position, and that is extended down below the surface of the subsea structure in an operating position, such as to manipulate the valve. The crawler may then position in relative the interface and then activate the tool.

5 There may be numerous crawlers in the same subsea system, and the different crawlers may have different properties and tasks. The crawlers may work alone, in pair, or they may be parts of a larger group of crawlers to perform operations that require e.g. more power, torque capacity etc. Such operations may include opening or closing of larger valves, movement of subsea elements, 10 replacement of modules etc.

 The crawlers may have one or more of the following properties: recharging means for charging itself, and or other crawlers and or other subsea equipment, wireless communication means, inspection means such as camera, noise detection, vibration detection, torque tools, hydraulic tools, storage 15 capacity i.e. to transfer data from sensors to the main control system or similar, onboard units which function as a or part of a control system. By having the crawlers equipped with an onboard control system, one may reduce the need for full control systems at several places in the subsea system, as the crawler may move around and connect itself to different subsea equipment, and thereby 20 provide a control module for the subsea system. The crawler with the onboard control system may also be used as temporary backup systems for other control modules subsea. If an error occurs, a crawler may attach itself to the system, thereby providing a backup of the control system until maintenance may be performed. A crawler may also be equipped with handling means, to pick up 25 smaller replaceable elements from storage and replace a malfunctioning element in the subsea system.

 The crawlers may have means for wireless communication with a termination head and or for communication with other crawlers and possibly also to an operator. The termination head may receive data from the crawler and or 30 give instructions/data to the crawler. This communication may also be transferred with a plug-in solution. The termination head may have charging means, e.g. a recharge station, for charging the crawler with power, e.g. electrically through a plug-in solution or through wireless power transfer, e.g. inductive charging. The charging means may also have data-transmission 35 properties for sending or receiving data to and from the crawler.

The recharging means may be rechargeable batteries or similar.

One crawler may recharge other crawlers, either directly through power produced in an own power generating system, or, alternatively, by first charging the rechargeable battery at the termination head and then recharge the other crawler. After such operations, the crawler that has performed the charging may return to the termination head e.g. for re-supply of power or for performing other tasks.

The power source for the termination head may be delivered through a subsea umbilical, power through an umbilical or wires from the surface, surrounding seawater, subsea power plant, subsea turbine, energy generated from a well stream, thermocouple, battery etc.

The crawlers may be provided with ROV-lifting means, such that if a crawler is damaged or for some reason is malfunctioning, it may be lifted to the surface by a ROV or similar for repair.

In an embodiment, the subsea system comprises sensor modules. The sensor modules is preferably a self contained unit designed to perform low power, low bandwidth sensor functions like temperature, vibration and pressure reporting.

The subsea system may also comprise crawlers having means for cleaning the surface of the subsea installation for the crawlers.

According to another aspect the subsea system may comprise a subsea installation and a subsea structure with negotiable surface with a pathway forming a negotiable surface between the installation and the structure. The subsea structure is in such a system a subsea installation without the recharging station. In such a setting one may envisage that one crawler is positioned on the subsea structure for instance as a backup control module, which then is recharged by another crawler, moving at intervals between the crawler at the subsea structure and a recharge station at a subsea installation, using the pathways in the system.

In an aspect, the system may comprise a tool storage device, accessible for the crawler to retrieve, or position a tool to use or unit to be replaced in the subsea system.

In an aspect, the crawler may have means for wireless power transfer to and from the umbilical termination head, another crawler or a power source.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other characteristics of the invention will be clear from the following description of a preferential form of embodiment, given as a non-restrictive example, with reference to the attached drawings wherein:

5 Fig. 1 discloses an embodiment of a crawler, in a front-view, according to the present invention with a torque tool in a retracted position;

Fig. 2 discloses an opposite view of the crawler in Fig. 1;

Fig. 3 discloses an embodiment of a crawler with a torque tool in an extended position;

10 Fig. 4 discloses a crawler on a subsea structure parked at a termination head;

Fig. 5 discloses a crawler on a subsea structure on its way to or from the termination head;

15 Fig. 6 discloses a crawler with the torque tool in an extended position manipulating a valve;

Fig. 7 discloses a crawler parked at an actuator;

Fig. 8 discloses a crawler venturing over the side of a subsea structure;

Fig. 9 discloses a crawler on a vertical surface of a subsea structure;

Fig. 10 discloses an embodiment of a termination head;

20 Fig. 11 discloses an example of an actuator according to the invention;

Fig. 12 discloses an example of the view from a forward navigation camera on a crawler;

Fig. 13 discloses an example of pathways for the crawler on the subsea system; and

25 Fig. 14 discloses an embodiment of a torque tool according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 discloses a crawler 1 with a crawler body 8, in a front-view, according to an embodiment of the present invention, the crawler 1 having a torque tool 2 and a torque tool motor 6. In the shown embodiment the torque tool 2 is in a retracted position. Further, the crawler 1 is provided with a plurality of wheels 5. The wheels 5 and/or the body 8 may be made of a magnetic material or other sticking means such that it will stick to a surface (not shown). The body 8 of the crawler 1 may in a preferred embodiment comprise a control system, batteries, locomotion drives etc. (not disclosed in the Figures). The

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crawler 1 is provided with cameras 3 for e.g. navigation or inspection. Wireless communication means, exemplified as a number of Wi-Fi antennas 7, are arranged on the body 8 of the crawler 1 for wireless communication with e.g. a termination head, other crawlers, a control system (no one of which is disclosed in Fig. 1). The wheels 5 provide 360 degrees movability of the crawler 1 along a surface. The crawler 1 has lifting means 4 such that it can be lifted to the surface for e.g. maintenance, repair, or other purposes.

Fig. 2 shows a similar crawler 1 as in Fig. 1 from an opposite view, having a charging coupling 9 for, e.g., inductive/electric charging and/or charging of hydraulic power.

Fig. 3 shows the torque tool 2 in an extended position. The torque tool 2 and the torque tool motor 6 have been moved relative the crawler body 1 in relation to the position disclosed in Figures 1 and 2.

Fig. 4 shows the crawler 1 on a subsea structure 10 when the crawler is parked at a recharge station 16 in a termination head 11. The subsea structure 10 has plane surfaces making it easy for the crawler 1 to move around in any direction. The termination head 11 has fastening means 12 for connection to the subsea structure 10. It is also disclosed a valve 13 on the subsea structure 10 to be manipulated by the torque tool 2 on the crawler 1.

Fig. 5 shows the same as Fig. 4, but in this Figure the crawler 1 has left, or alternatively, is entering, the termination head 11. A number of valves 13 are disclosed in the foreground and sensor modules 15 are shown in the background. The sensor modules 15 is a self-contained unit designed to perform low power, low bandwidth sensor functions like temperature, vibration and pressure reporting. The sensor modules 15 may comprise a wireless communication means, an energy harvesting module, a connection to production fluids, transducers and control electronics.

Fig. 6 discloses a crawler 1 with the torque tool 2 in an extended position manipulating a valve 13 on a subsea structure 10.

Fig. 7 discloses the crawler 1 parked at an actuator 14 for performing an operation such as filling hydraulic fluid, charging the actuator 14. The actuator 14 can be hydraulic, electric or a combination thereof. In an alternative embodiment, the sensor modules (ref. Fig. 5) may be charged in the same way as the actuator 14 in the disclosed embodiment.

Fig. 8 shows an embodiment of the invention where the crawler 1 is venturing over the side of the subsea structure 10. For the crawler 1 to be able to move over such corners, it is preferably arranged with a cone-shape 17 or any other suitable shape in the part of the crawler body 8 which lies between the wheels in front and the wheels in the back of the crawler body 8.

Fig. 9 discloses the crawler 1 when on a vertical face of a subsea structure 10. Sticking means in the wheels 5 or in the crawler body 8 make sure that the crawler 1 sticks to the surface of the subsea structure 10, due to magnetic force, tape or similar.

Fig. 10 discloses an embodiment of a termination head 11 according to the invention. The termination head 11 is connected to a power source through a power connection 17. The power source may be a subsea umbilical, power through an umbilical or wires from the surface, surrounding seawater, subsea power plant, subsea turbine, energy generated from a well stream, thermocouple etc.

Fig. 11 discloses an example of an actuator 14 according to the invention. The actuator may be provided with fastening elements 18 for connection with a structure (not shown).

Fig. 12 discloses an example of the view from a forward navigation camera 2 on the crawler 1, including an actuator 14, sensor modules 15 and valve 13.

Fig. 13 discloses examples of pre-programmed or pre-made safe pathways 19 for the crawler 1 on the subsea system. It shall be understood that the crawler 1 in one embodiment may move in all directions on the surface of the subsea system and that the disclosed pathways 19 is to be considered as being illustrative. In another embodiment the pathways may be pre-formed tracks for the crawler 1 to follow.

Fig. 14 discloses an embodiment of a torque tool 2 according to the invention. The torque tool 2 comprises lifting means 4 in an upper end thereof. Further, the torque tool 2 comprises a controller 22, a torque tool motor 6, a gear box 21 and sockets 20.

The invention is herein described in non-limiting embodiments. A person skilled in the art will understand that there may be made alterations and modifications to the embodiments that are within the scope of the invention as

defined in the attached claims, and elements or features of the different embodiments may be combined in any configuration.

CLAIMS:

1. A subsea system comprising:
a subsea installation having at least one negotiable surface and at least one recharge station;
5 at least one crawler freely movable on the surface of the subsea installation;
wherein each crawler has rechargeable means for charging by at least the recharge station.
2. The subsea system according to claim 1, wherein the subsea
10 installation further comprises at least one umbilical termination head, the umbilical termination head being connectable to at least one power source and is in contact with at least one recharge station.
3. The subsea system according to claim 2, wherein at least one recharge station forms part of the umbilical termination head.
- 15 4. The subsea system according to claim 1 or 2 or 3, wherein the subsea installation further comprises communication means, and at least one crawler has communication functions for communication with the communication means.
5. The subsea system according to claim 4, wherein the
20 communication means and communication functions comprises wireless communication elements.
6. The subsea system according to one of the preceding claims, wherein at least one crawler comprises a control module pack which is adaptable to control subsea systems to which the crawler attaches.
- 25 7. The subsea system according to one of the preceding claims, wherein at least one crawler comprises operating devices for manipulating subsea components.
8. The subsea system according to any of claims 3 - 7, wherein the operating devices comprises an extendable torque tool for manipulating, e.g.,
30 valves.
9. The subsea system according to any of the preceding claims, wherein the system comprises a tool storage device, accessible for the crawler to retrieve or position a tool to use or unit to be replaced in the subsea system.

10. The subsea system according to any of the preceding claims, wherein at least one crawler has sticking means for contact with the negotiable surface of the subsea structure.

5 11. The subsea system according to any of claims 1 - 10, wherein at least one crawler further comprises navigation cameras.

12. The subsea system according to any of claims 1 - 11, wherein the recharge station and the rechargeable means are inductive.

10 13. The subsea system according to any of claims 2 - 12, wherein the umbilical termination head is provided with a guiding arrangement for cooperation with an extending portion on the crawler for charging.

14. The subsea system according to any of the preceding claims, wherein at least one crawler has means for re-charging other modules on the subsea installation.

15 15. The subsea system according to any of the preceding claims, wherein the system comprises a subsea installation and a subsea structures with negotiable surface with a pathway forming a negotiable surfaces between the installation and the structure.

20 16. The subsea system according to any of the preceding claims, wherein the crawler has means for wireless power transfer to and from the umbilical termination head, another crawler or a power source.