A downhole equipment suspension and lateral power system for a subsea well including a suspension apparatus which is supportable above the tubing hanger and within the internal bore of the subsea production system. A power penetrator is laterally coupleable to the suspension apparatus. A cable is extendable from the suspension apparatus to suspend and power downhole equipment, such as an electric submersible pump. A communication line is extendable from the suspension apparatus to provide power to the downhole equipment.
DOWNHOLE EQUIPMENT SUSPENSION
AND LATERAL POWER SYSTEM

BACKGROUND

[0001] Drilling and producing offshore oil and gas wells includes the use of offshore facilities for the exploitation of underwater petroleum and natural gas deposits. A typical subsea system for drilling and producing offshore oil and gas can include the installation of an electrical submersible pumping ("ESP") system that can be used to assist in production.

[0002] Normally, when ESPs are used with wells they are used during production to provide a relatively efficient form of "artificial lift" by pumping the production fluids from the wells. By decreasing the pressure at the bottom of the well bore below the pump, significantly more oil can be produced from the well when compared with natural production.

[0003] ESPs include both surface components housed in the production facility or on an oil platform, and sub-surface components located in the well. The surface components include the motor controller, which can be a variable speed controller, and surface cables and transformers. Subsurface components typically include the pump, motor, seal, and cables. Sometimes, a liquid/gas separator is also installed. The pump may include multiple stages, with the number of stages being determined by the operating requirements. Each stage includes a driven impeller and a diffuser that directs flow to the next stage of the pump. The power to run the ESP comes from a source connected with the ESP via cable from the surface. The power source could be alternating current or direct current. Typically, the cable is run from the surface vertically through the well, including through any components above the subsea production tree (e.g., intervention riser or blowout preventer stack).

[0004] An issue with existing methods for suspending downhole equipment, including ESPs, is suspending and providing power to the downhole equipment. In general, power communication means (e.g., cables) must be run vertically through the top of the tree and tubing hanger and through the well. Accordingly, the blowout preventer ("BOP") stack must be removed prior to powering the ESP. Removing this equipment can be a very costly and potentially dangerous endeavor. Accordingly, a cost effective and safer alternative to adding downhole equipment to a well, namely an ESP, is desired.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A better understanding of the various disclosed system and method embodiments can be obtained when the following detailed description is considered in conjunction with the drawings, in which:

[0006] FIG. 1 shows an embodiment of a production system with a downhole equipment suspension and power system;

[0007] FIG. 2 shows an embodiment of an adaptor spool including multiple lateral power penetrators;

[0008] FIG. 3 shows another embodiment of a production system with a downhole equipment suspension and power system including a vertical tree;

[0009] FIG. 4 shows another embodiment of a production system with a downhole equipment suspension and power system including a vertical tree and an adaptor spool;

[0010] FIG. 5 shows another embodiment of a production system with a downhole equipment suspension and power system including a horizontal tree and an adaptor spool;

[0011] FIG. 6 shows another embodiment of a production system with a downhole equipment suspension and power system including a horizontal tree;

[0012] FIG. 7 shows another embodiment of a production system with a downhole equipment suspension and power system including a vertical tree and an adaptor spool with a lateral port;

[0013] FIG. 8 shows another embodiment of a production system with a downhole equipment suspension and power system including a horizontal tree and an adaptor spool with a lateral port;

[0014] FIG. 9 shows another embodiment of a production system with a downhole equipment suspension and power system including a vertical tree and a vertical connection;

[0015] FIG. 10 shows another embodiment of a production system with a downhole equipment suspension and power system including an adapter spool with a lateral port and a vertical connection; and

[0016] FIG. 11 shows another embodiment of a production system with a downhole equipment suspension and power system including a horizontal tree, an adaptor spool with a lateral port and a vertical connection.

DETAILED DESCRIPTION

[0017] The following discussion is directed to various embodiments of the invention. The drawing figures are not necessarily to scale. Certain features of the embodiments may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. Although one or more of these embodiments may be preferred, the embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. It is not to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results. In addition, one skilled in the art will understand that the following description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to intimate that the scope of the disclosure, including the claims, is limited to that embodiment.

[0018] Certain terms are used throughout the following description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function. Certain features and components herein may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in interest of clarity and conciseness.

[0019] In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to . . . ." Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection, or through an indirect connection via other devices, components, and connections. In addition, as used herein, the terms "axial" and "axially" generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms "lateral" and "laterally" generally mean about perpen-
dicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a lateral distance means a distance measured perpendicular to the central axis.

[0020] Accordingly, disclosed herein is a downhole equipment suspension and later power system for a well. The system is suitable for production, circulation, workover, and injection scenarios. The system may utilize an adaptor spool (s), a vertical, horizontal, or modular production tree, tubing spool, high pressure wellhead housing, or any equipment in which a tubing hanger could be landed. The suspension and power system may be used for connecting to any type of downhole equipment. For example, the downhole equipment may include an electric submersible pump system for pumping production fluids. Alternative embodiments of the suspension and lateral power system are disclosed.

[0021] FIG. 1 is an illustrative embodiment of a subsea production system 101 including a subsea tubing head 110. The production system 101 also includes a downhole equipment suspension and power system. In this embodiment, the subsea tubing head 110 can be attached above a high pressure wellhead housing (not shown in FIG. 1). Additionally, instead of a tubing head, the embodiment shown in FIG. 1 may include a subsea high pressure wellhead housing 110.

[0022] The downhole equipment suspension and power system includes a suspension apparatus 106 supported by an adaptor spool 124. The adaptor spool 124 is landed above the tubing head 110. The adaptor spool 124 can be installed prior to, during, or after the well is completed. As an example, the suspension apparatus 106 shown is a cable hanger which lands and locks into the adaptor spool 124 below environmental barrier 109. In the embodiment shown in FIG. 1, environmental barrier 109 is a valve. In other embodiments, there may be more than one environmental barrier above the suspension apparatus. A debris cap 126 can optionally be located above the adaptor spool 124. The debris cap 126 provides an environmental barrier. In other embodiments, other barrier equipment such as an intervention riser may be used.

[0023] In other embodiments, the environmental barrier 109 could also be any pressure barrier, such as a plug. Pressure barriers other than valves can reduce the complexity of the adaptor spool 124 (e.g., size and configuration) because there is no requirement for a valve bonnet. Reducing the size and complexity of the adaptor spool 124 also provides additional room for the lateral power penetrator 103, which is discussed in more detail below.

[0024] A running tool may be used to run, land, and lock the suspension apparatus 106 into the adaptor spool 124. The running tool may include an electrical connection to monitor continuity of power and signal electrical lines when running the suspension apparatus 106 and also may provide access to the hydraulic lines controlling an emergency disconnect feature.

[0025] The downhole equipment suspension and power system also includes downhole equipment 130 installed in the production tubing (not shown in FIG. 1). The downhole equipment may be any type of equipment. For example, the downhole equipment 130 may include a pump operated by electrical power, hydraulic power, or both electrical and hydraulic power. The downhole equipment 130 may be installed with the production tubing or after the production tubing is installed. The downhole equipment may also be an internal completion system, including sliding sleeves, chokes, valves, and sensors (e.g., temperature, pressure, and flow).

[0026] The downhole equipment suspension and power system also includes a cable 107 that extends through the production bore of the tubing head 110 and suspends downhole equipment 130 from the suspension apparatus 106. The cable 107 may be any line appropriate for suspension of the downhole equipment 130, e.g., coiled tubing, tubing, pipe, etc. The cable 107 may include one or more communication lines 108. Communication lines 108 may include one or more of electrical conductors, hydraulic conduits, and/or fiber optic cables that can be used to power and operate the downhole equipment 130. In some embodiments, the communication lines 108 are disposed along the outside of the cable 107. There may be a wrap or tie surrounding one or more portions of the cable 107 and communication lines 108 to keep the communication lines 108 against or otherwise in close proximity to the cable 107. In other embodiments, the communication lines 108 may be wrapped helically around the cable 107. The communication lines 108 may also be encapsulated inside the cable 107 for protection. The cable 107 may not require any internal pressure compensation. There may also be an emergency disconnect function to disconnect the cable 107 from the downhole equipment 130 in the event that the downhole equipment 130 or cable 107 is stuck downhole and cannot be retrieved during installation and/or retrieval operations. Alternative embodiments may comprise more than one cable 107 and multiple communication lines 108.

[0027] The suspension and power system also includes at least one power penetrator 103 laterally coupled to the suspension and power system. The power penetrator 103 can be deployed by remotely operated vehicle. The power penetrator 103 is used for connecting an external power source 132 with the downhole equipment 130 in power communication through the communication lines 108.

[0028] In the embodiment illustrated in FIG. 1, the power penetrator 103 is shown penetrating the adaptor spool 124 perpendicular to the production bore in order to access the suspension apparatus 106. However, the power penetrator 103 can be laterally coupled through subsea equipment other than the adaptor spool 124 provided that the power penetrator 103 accesses the suspension apparatus 106 laterally. In the embodiment illustrated in FIG. 1, the power penetrator 103 is shown laterally coupled to the adaptor spool at about a 90° angle. However, the power penetrator 103 can be laterally coupled at any angle. In one embodiment, the power penetrator may comprise a single line including electrical, hydraulic, and fiber optic lines.

[0029] FIG. 2 illustrates an embodiment of the adaptor spool 224, comprising multiple power penetrators 203a, 203b, and 203c for the same or different types of communication. As an example only, the power penetrators 203a, 203b, and 203c may each comprise a different power phase, or one penetrator may provide fiber optic communication while another provides hydraulic fluid. Like the embodiment shown in FIG. 1, the embodiment shown in FIG. 2 comprises an environmental barrier 209 located in the adaptor spool 224. In the embodiment shown in FIG. 2, environmental barrier 209 is a valve. In other embodiments, the environmental barrier 209 could be a plug. In other embodiments, there may be more than one environmental barrier 209 above the suspension apparatus. The embodiment may further comprise a hydraulic fluid stub 246 and a dielectric flush line 248. Other
embodiments of the invention can include any number of additional power penetrators. Although shown in the same plane, the power penetrators may be equally spaced around the adaptor spool 224. Alternative embodiments allow for the power penetrator lines to be spaced around the wellhead equipment in any arrangement that allows for power to reach the downhole equipment. Other embodiments may include more than one lateral power penetrator, wherein each power penetrator comprises one or more lines.

As shown in FIG. 1, the power penetrator 103 couples to the suspension apparatus 106 through the adaptor spool 124. Seals (shown schematically as black dots in exemplary locations on FIGS. 1-11) can be provided above and below the point where the lateral power penetrator 103 couples to the adaptor spool 124. These seal the adaptor spool 124 and suspension apparatus to form a sealed enclosure through which the power penetrator 103 couples to the suspension apparatus 106. The cable 107 runs from the suspension apparatus 106 down the well through the production tubing. Various connections for communication lines 108 may be used as known to those skilled in the art as appropriate.

FIG. 3 is another illustrative embodiment of a subsea production system 301 including a subsea vertical production tree 310 attached above a tubing head spool 316. The production system 301 also includes a downhole equipment suspension and power system. The production tree 310 could also be any other type of subsea vertical production tree, such as a vertical monobore production tree. A tubing hanger 304 is landed in the tubing head spool 316 and supports production tubing 308 that extends into the well.

The downhole equipment suspension and power system includes a suspension apparatus 306 landed in the subsea vertical production tree 310, above the tubing hanger 304. The suspension apparatus 306 can be installed prior to, during, or after the well is completed. As an example, the suspension apparatus 306 shown is a cable hanger which lands and locks into the subsea vertical production tree 310 above the tubing hanger 304 and below environmental barrier 309. In the embodiment shown in FIG. 3, environmental barrier 309 is a valve. In other embodiments, the environmental barrier 309 could also be any pressure barrier, such as a plug.

The downhole equipment suspension and power system also includes downhole equipment (not shown in FIG. 3) installed in the production tubing 308. The downhole equipment may be any type of equipment. For example, the downhole equipment may include a pump operated by electrical power, hydraulic power, or both electrical and hydraulic power, hydraulic supply, or fiber optics. The downhole equipment may be installed with the production tubing 308 or after the production tubing 308 is installed.

The downhole equipment suspension and power system also includes a cable 307 that extends through the production bores of the production tree 310 and the tubing hanger 304 and suspends downhole equipment from the suspension apparatus 306. The cable 307 may be any line appropriate for load-bearing suspension of the downhole equipment, e.g., coiled tubing, tubing, pipe, etc. There may also be one or more communication lines (not shown in FIG. 3) running along the cable 307 that may include one or more of electrical conductors, hydraulic conduits, and/or fiber optic cables that can be used to power and operate the downhole equipment. These communication lines may be encapsulated inside the cable 307 for protection, disposed along the outside of the cable 307, or helically wrapped around the cable 307. The cable 307 may not require any internal pressure compensation. There may also be an emergency disconnect function to disconnect the cable 307 from the downhole equipment in the event that the downhole equipment or cable 307 is stuck downhole and cannot be retrieved during installation and/or retrieval operations. Alternative embodiments may comprise more than one cable 307 and multiple communication lines.

Also in this embodiment, the production tree 310 includes an annulus bypass 322 such that the annular area surrounding the production tubing 308 is in fluid communication with the vertical bore of the production tree 310 above the tubing hanger 304. The annulus bypass 322 may optionally include one or more valves 328.

The suspension and power system also includes at least one power penetrator 303 that is laterally coupled to the suspension and power system. The power penetrator 303 can be deployed by a remotely operated vehicle. The power penetrator 303 is used for connecting an external power source 332 with the downhole equipment 330 in power communication through the communication lines.

In the embodiment illustrated in FIG. 3, the power penetrator 303 is shown laterally coupling to the subsea production tree 310 at about a 90° angle with respect to the production bore. However, the power penetrator 303 can be laterally coupled to the equipment at any angle. As shown, the power penetrator 303 couples to the suspension apparatus 306 through the subsea production tree 310. The cable 307 runs from the suspension apparatus 306 down the well through the production tubing 308. Various electrical connections for the communication lines may be used as known to those skilled in the art as appropriate.

In operation, produced fluids are pumped upward from the well inside of the production tubing 308 and outside of the cable 307 and then out through the vertical tree lateral production bore 313 below the suspension apparatus 306. The lateral production bore comprises one or more production/injection valves 334 for controlling flow of fluids from or into the wellbore. The suspension system provides the necessary multiple environmental barriers, e.g., valves or plugs. Power is provided to the downhole equipment through the power penetrator 303 connection to the external power source 332, which may provide power as electrical, hydraulic, or both.

FIG. 4 is an illustrative embodiment of a subsea production system 401 including a subsea vertical production tree 410 attached above a high pressure wellhead housing or tubing head spool 416. The production system 401 also includes a downhole equipment suspension and power system.

A tubing hanger (not shown in FIG. 4) is landed in the high pressure wellhead housing or tubing head spool 416. The tubing hanger supports production tubing (not shown in FIG. 4) which extends into the well. A production casing may surround the production tubing in one embodiment of the invention, creating an annular space.

The downhole equipment suspension and power system includes a suspension apparatus 406 supported by an adaptor spool 424. The adaptor spool 424 is landed above the subsea production tree 410. The adaptor spool 424 can be installed prior to, during, or after the well is completed. As an example, the suspension apparatus 406 shown is a cable hanger which lands and locks into the adaptor spool 424.
below an environmental barrier 409. A debris cap, intervention blowout preventer or intervention riser can be located above the adaptor spool 424.

[0042] The downhole equipment suspension and power system also includes downhole equipment (not shown in FIG. 4) installed in the production tubing. The downhole equipment may be any type of equipment. For example, the downhole equipment may include a pump operated by electrical power, hydraulic power, or both electrical and hydraulic power. The downhole equipment may be installed with the production tubing or after the production tubing is installed.

[0043] The downhole equipment suspension and power system also includes a cable 407 that extends through the bore of the production tree 410 and suspends downhole equipment from the suspension apparatus 406. The cable 407 may be any line appropriate for suspension of the downhole equipment, e.g., coiled tubing, tubing, pipe, etc.

[0044] There may also be one or more communication lines (not shown in FIG. 4) running along the cable 407 that may include one or more of electrical conductors, hydraulic conduits, and/or fiber optic cables that can be used to power and operate the downhole equipment. These communication lines may be encapsulated inside the cable 407 for protection, disposed along the outside of the cable 407, or helically wrapped around the cable 407. The cable 407 may not require any internal pressure compensation. There may also be an emergency disconnect function to disconnect the cable 407 from the downhole equipment in the event that the downhole equipment or cable 407 is stuck downhole and cannot be retrieved during installation and/or retrieval operations. Alternative embodiments may comprise more than one cable 407 and multiple communication lines.

[0045] Also in this embodiment, the subsea production tree 410 includes an annulus bypass 422 with one or more annulus bypass valves 428 and one or more valves 442 in the vertical run of the production bore.

[0046] The suspension and power system also includes at least one power penetrator 403 which is laterally coupled to the suspension and power system. The lateral power penetrator 403 can be deployed by remotely operated vehicle. The power penetrator 403 is used for connecting an external power source 432 with the downhole equipment in power communication through the communication lines.

[0047] In the embodiment illustrated in FIG. 4, the power penetrator 403 is shown penetrating the adaptor spool 424 perpendicular to the production bore in order to access the suspension apparatus 406. However, the power penetrator 403 can be laterally coupled through subsea equipment other than an adaptor spool provided that the power penetrator 403 accesses the suspension apparatus 406 laterally. In the embodiment illustrated in FIG. 4, the power penetrator 403 is shown laterally coupled to the adaptor spool at about a 90° angle. However, the power penetrator 403 can be laterally coupled at any angle.

[0048] As shown, the power penetrator 403 couples to the suspension apparatus 406 through the adaptor spool 424. Seals can be provided above and below the point where the power penetrator 403 couples to the adaptor spool 424. These seal the adaptor spool 424 and suspension apparatus 406 together to form a sealed enclosure through which the power penetrator 403 couples to the suspension apparatus 406. The cable 407 runs from the suspension apparatus 406 down the well through the production tubing. Various electrical connections for the communication lines may be used as known to those skilled in the art as appropriate.

[0049] As shown as an example in FIG. 4, the subsea production tree 410 is installed above a tubing head spool 416 in which a tubing hanger can be landed. Alternatively, the subsea production tree 410 may be installed directly to the high pressure wellhead housing.

[0050] In operation, produced fluids are pumped upward from the well inside of the production tubing and outside of the cable 407 and then out through the tree lateral production bore 427 below the suspension apparatus 406. The suspension system provides the necessary multiple environmental barriers, e.g., valves or plugs. Power is provided to the downhole equipment through the power penetrator 403 connection to the external power source, which may provide power as electrical, hydraulic, or both through the communication lines. Should the production vertical tree 410 need to be removed for service, the suspension system, including the cable 407 and the downhole equipment may be removed and appropriate barriers set in place. The production vertical tree 410 may then be removed while leaving the tubing hanger and production tubing in place.

[0051] The downhole equipment suspension and lateral power system of the present disclosure can be used in a vertical, horizontal, or hybrid tree configuration. FIG. 5 is an illustrative embodiment of a subsea production system 501 including a subsea horizontal production tree 510 attached above a high pressure wellhead housing 516. The production system 501 also includes a downhole equipment suspension and lateral power system.

[0052] A tubing hanger 504 is landed in the horizontal production tree 510. The tubing hanger 504 supports production tubing 508 which extends into the well. A production casing may surround the production tubing 508 in one embodiment of the invention, creating an annular space.

[0053] The downhole equipment suspension and lateral power system includes a suspension apparatus 506 supported by an adaptor spool 524. The adaptor spool 524 is landed above the subsea production tree 510. The adaptor spool 524 can be installed prior to, during, or after the well is completed. As an example, the suspension apparatus 506 shown is a cable hanger which lands and locks into the adaptor spool 524 below an environmental barrier 509. A debris cap, intervention blowout preventer or intervention riser (not shown in FIG. 5) can be located above the adaptor spool 524.

[0054] The downhole equipment suspension and power system also includes a cable 507 that extends through the production bores of the production tree 510 and the tubing hanger 504 and suspends downhole equipment (not shown in FIG. 5) from the suspension apparatus 506. The cable 507 may be any line appropriate for suspension of the downhole equipment, e.g., coiled tubing, tubing, pipe, etc. There may also be one or more communication lines (not shown in FIG. 5) running along the cable 507 that may include one or more of electrical conductors, hydraulic conduits, and/or fiber optic cables that can be used to power and operate the downhole equipment. These communication lines may be encapsulated inside the cable 507 for protection, disposed along the outside of the cable 507, or helically wrapped around the cable 507. The cable 507 may not require any internal pressure compensation. There may also be an emergency disconnect function to disconnect the cable 507 from the downhole equipment in the event that the downhole equipment or cable 507 is stuck downhole and cannot be retrieved during installation and/or
retrieval operations. Alternative embodiments may comprise more than one cable 507 and multiple communication lines.

[0055] Also in this embodiment, the subsea production tree 510 includes an annulus bypass 522 and one or more annulus bypass valves 528.

[0056] The suspension and power system also includes at least one power penetrator 503 which is laterally coupled to the suspension and power system. The power penetrator 503 can be deployed by remotely operated vehicle. The power penetrator 503 is used for connecting an external power source 532 with the downhole equipment in power communication through the communication lines.

[0057] In the embodiment illustrated in FIG. 5, the power penetrator 503 is shown penetrating the adaptor spool 524 perpendicularly to the production bore in order to access the suspension apparatus 506. However, the power penetrator 503 can be laterally coupled through subsea equipment other than an adaptor spool provided that the power penetrator 503 accesses the suspension apparatus 506 laterally. In the embodiment illustrated in FIG. 5, the power penetrator 503 is shown laterally coupled to the adaptor spool at about a 90° angle. However, the power penetrator 503 can be laterally coupled at any angle.

[0058] As shown, the power penetrator 503 couples to the suspension apparatus 506 through the adaptor spool 524. Seals can be provided above and below the point where the power penetrator 503 couples to the adaptor spool 524. These seal the adaptor spool 524 and suspension apparatus 506 together to form a sealed enclosure through which the power penetrator 503 couples to the suspension apparatus 506. The cable 507 runs from the suspension apparatus 506 down the well through the production tubing 508. Various electrical connections for the communication lines may be used as known to those skilled in the art as appropriate.

[0059] As shown in FIG. 5, the subsea production tree 510 is installed directly to a high pressure wellhead housing 516. Alternatively, the subsea production tree 510 may be installed indirectly to the high pressure wellhead housing 516, e.g., by way of a tubing spool.

[0060] In operation, produced fluids are pumped upward from the well inside of the production tubing 508 and outside of the cable 507 and then out through the tree lateral production bore 527 below the suspension apparatus 506. The suspension system provides the necessary multiple environmental barriers, e.g., valves or plugs. Power is provided to the downhole equipment through the power penetrator 503 connection to the external power source 532, which may provide power as electrical, hydraulic, or both through the communication lines.

[0061] FIG. 6 is another illustrative embodiment of a subsea production system 601 including a subsea horizontal production tree 610 attached above a high pressure wellhead housing 616. The production system 601 also includes a downhole equipment suspension and lateral power system. A tubing hanger 604 is landed in the subsea horizontal production tree 610 and supports production tubing 608 that extends into the well.

[0062] The downhole equipment suspension and lateral power system includes a suspension apparatus 606 landed in the subsea horizontal production tree 610, above the tubing hanger 604. The suspension apparatus 606 can be installed prior to, during, or after the well is completed. As an example, the suspension apparatus 606 shown is a cable hanger which lands and locks into the subsea horizontal production tree 610 above the tubing hanger 604 and below environmental barrier 609. In the embodiment shown in FIG. 6, environmental barrier 609 is a valve. In other embodiments, the environmental barrier 609 could also be any pressure barrier, such as a plug.

[0063] The downhole equipment suspension and power system also includes a cable 607 that extends through the production bores of the production tree 610 and the tubing hanger 604 and suspends downhole equipment (not shown in FIG. 6) from the suspension apparatus 606. The cable 607 may be any line appropriate for suspension of downhole equipment 630, e.g., coiled tubing, tubing, pipe, etc. There may also be one or more communication lines (not shown in FIG. 6) running along the cable 607 that may include one or more of electrical conductors, hydraulic conduits, and/or fiber optic cables that can be used to power and operate the downhole equipment. These communication lines may be encapsulated inside the cable 607 for protection, disposed along the outside of the cable 607, or helically wrapped around the cable 607. The cable 607 may not require any internal pressure compensation. There may also be an emergency disconnect function to disconnect the cable 607 from downhole equipment in the event that the downhole equipment or cable 607 is stuck downhole and cannot be retrieved during installation and/or retrieval operations. Alternative embodiments may comprise more than one cable 607 and multiple communication lines.

[0064] Also in this embodiment, the production tree 610 includes an annulus bypass 622 such that the annular area surrounding the production tubing 608 is in fluid communication with the vertical bore of the production tree 610 above the tubing hanger 604. The annulus bypass 622 may optionally include one or more valves 628.

[0065] The suspension and power system also includes at least one power penetrator 603 that is laterally coupled to the suspension and power system. The power penetrator 603 can be deployed by a remotely operated vehicle. The power penetrator 603 is used for connecting an external power source 632 with the downhole equipment in power communication through the communication lines.

[0066] In the embodiment illustrated in FIG. 6, the power penetrator 603 is shown laterally coupling to the subsea production tree 610 at about a 90° angle with respect to the production bore. However, the power penetrator 603 can be laterally coupled to the equipment at any angle. As shown, the power penetrator 603 couples to the suspension apparatus 606 through the subsea production tree 610. The cable 607 runs from the suspension apparatus 606 down the well through the production tubing 608. Various electrical connections for the communications lines may be used as known to those skilled in the art as appropriate. In operation, produced fluids are pumped upward from the well inside of the production tubing 608 and outside of the cable 607 and then out through the tree lateral production bore 627 below the suspension apparatus 606. The suspension system provides the necessary multiple environmental barriers, e.g., valves or plugs. Power is provided to the downhole equipment through the power penetrator 603 connection to the external power source 632, which may provide power as electrical, hydraulic, or both through the communication lines.

[0067] FIG. 7 is an illustrative embodiment of the subsea production system illustrated in FIG. 4, further comprising a second lateral production/injection bore 713. FIG. 8 is an illustrative embodiment of the subsea production system
illustrated in FIG. 5, further comprising a second lateral production/injection bore 813. As illustrated in FIGS. 7 and 8, the adaptor spool may optionally include a lateral production/injection bore. The lateral production/injection bore of the adaptor spool can facilitate production of produced fluids from the well and injection of fluids into the well.

[0068] FIG. 9 is an illustrative embodiment of the subsea production system illustrated in FIG. 3, further comprising a vertical connection or passage 940 extending from the lateral bore 813 and tying into the vertical bore of tree 310 above the suspension apparatus 506 and below the environmental barrier 309.

[0069] FIG. 10 is an illustrative embodiment of the subsea production system illustrated in FIGS. 4 and 7, further comprising a vertical connection or passage 1040 extending from the second lateral bore 713 and tying into the adaptor spool bore 424 above the suspension apparatus 406 and below the environmental barrier 409.

[0070] FIG. 11 is an illustrative embodiment of the subsea production system illustrated in FIGS. 5 and 8, further comprising a vertical connection or passage 1140 extending from the second lateral bore 813 and tying into the adaptor spool bore 524 above the suspension apparatus 506 and below the environmental barrier 509.

[0071] The vertical connections/passages illustrated in FIGS. 9-11 provide for additional functionality after downhole equipment installation, including well flow test evaluation and downhole equipment test run.

[0072] The embodiments described above may include downhole equipment for pumping produced fluids from a well or injecting fluids into a well. For instance, the disclosed production and lateral power system can be used to operate downhole equipment such as an electric submersible pump for providing artificial lift to enhance recovery of produced fluids. Alternatively, the suspension and lateral power system can be used to injection fluids into the well, such as chemicals.

[0073] The various embodiments disclosed above may optionally include a means for providing fresh or recycled lubricants, such as oil or dielectric lubricant, to the downhole equipment. Traditionally, downhole pump motors are less reliable than conventional seabed pump motors and pumps because they are in harsher environments and have not previously been able to receive fresh or recycled lubricating oil. Embodiments of the present invention may include means for providing fresh or recycled lubricating oil to the downhole equipment. For instance, embodiments of the present invention may include a hydraulic conduit routed on a path from the adaptor spool 424, or the suspension apparatus 406, to the cable 407 and down to downhole equipment. Fresh oil could travel this path by pressure and feed to downhole equipment. The pressure pushes the oil through and out of the pump motor and pumps and into the production flow. Other embodiments could also include a closed loop oil recycling arrangement. The closed loop arrangement could be used to deliver oil to the pump motor and pumps, receive the oil back and circulate through an oil recycling process facility located on the adaptor spool 424.

[0074] Providing fresh or recycled lubricating oil to the downhole equipment extends the life of the downhole equipment, resulting in cost efficiencies. An apparatus for providing fresh and/or recycled lubricating oil to the downhole equipment may be incorporated in any embodiment of the disclosed invention. For instance, the apparatus for providing fresh and/or recycled lubricating oil may be incorporated in any embodiment of this disclosure, including those illustrated in FIGS. 1-8, and any other combinations of the disclosure.

[0075] The present disclosure provides for flexibility in installation. As discussed above, there are various options for configuration and the use of multiple components. For instance, the tubing hanger can be landed in the production member (e.g., tree, high pressure wellhead housing, etc.) or in a spool or head. In addition, the suspension apparatus can be landed in the production trees or in an adaptor spool. Further, the power penetrator may be laterally coupled to the production member or to the adaptor spool.

[0076] The present disclosure allows for the addition of downhole equipment, e.g., an ESP, to an existing well without having to pull the tree or tubing hanger and make modifications. This provides a safe and cost-effective way to add the downhole equipment when eventually needed due to one or more valves being located above the suspension apparatus, e.g., cable hanger, and the fact that the power can be turned on to the ESP with a barrier in place above the production tree, such as an intervention riser or blowout preventer stack.

[0077] While specific embodiments have been shown and described, modifications can be made by one skilled in the art without departing from the spirit and teaching of this invention. The embodiments as described are exemplary only and are not limiting. Many variations and modifications are possible and are within the scope of the invention. Accordingly, the scope of protection is not limited to the embodiments described, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims.

What is claimed is:
1. A subsea production system for a subsea well including: a tubing hanger configured to suspend production tubing extending into the subsea well; downhole equipment locatable inside the production tubing in the subsea well; a suspension apparatus supportable above the tubing hanger; a power penetrator laterally coupleable to the suspension apparatus; a cable extendable from the suspension apparatus and configured to suspend the downhole equipment; and a communication line extendable from the suspension apparatus and configured to provide power to the downhole equipment.

2. The system of claim 1, further comprising an adaptor spool including an internal, vertical bore.

3. The system of claim 2, further including a subsea production member and wherein the adaptor spool is connectable directly or indirectly to the subsea production member.

4. The system of claim 3, wherein the subsea production member is a subsea production tree.

5. The system of claim 4, wherein the subsea production tree is one of a vertical tree or a horizontal tree.

6. The system of claim 3, wherein the subsea production member is at least one of a spool and a head.

7. The system of claim 3, wherein the subsea production member is a high pressure wellhead housing.

8. The system of claim 1, further including: a power source external to the subsea production member; and wherein the power source is configured to communicate power through the power penetrator.
9. The system of claim 2, wherein the power penetrator is laterally coupleable to the suspension apparatus from outside the adaptor spool.

10. The system of claim 1, wherein the communication line includes at least one of an electrical conductor, a hydraulic conduit, and a fiber optic cable.

11. The system of claim 1, wherein the communication line is locatable within the cable.

12. The system of claim 1, further including multiple power penetrators.

13. The system of claim 1, wherein the downhole equipment includes a pump operable by at least one of electrical power and hydraulic power.

14. The system of claim 13, wherein the downhole equipment includes a lubricant circulating system and a lubricant recycle system.

15. The system of claim 2, further including an environmental barrier in the adaptor spool internal bore above the suspension apparatus.

16. The system of claim 15, wherein the environmental barrier includes at least one of a valve and a plug.

17. A downhole equipment suspension and power system for a subsea production system including a subsea production member, a tubing hanger, and a production tubing extending into a subsea well, the suspension and power system including:

an adaptor spool including an internal bore and connectable with the subsea production system;

a suspension apparatus supportable within the internal bore of the adaptor spool;

an environmental barrier locatable in the adaptor spool internal bore above the suspension apparatus;

a power penetrator laterally coupleable to the suspension apparatus;

downhole equipment installable in the production tubing in the well;

a cable extendable from the suspension apparatus and configured to suspend the downhole equipment; and

a communication line extendable from the suspension apparatus and configured to provide power to the downhole equipment.

18. The system of claim 17 further including a power source configured to communicate power through the power penetrator.

19. The system of claim 17, wherein the power penetrator is laterally coupleable to the suspension apparatus from outside the adaptor spool.

20. The system of claim 17, wherein the communication line includes at least one of an electrical conductor, a hydraulic conduit, and a fiber optic cable.

21. The system of claim 17, wherein the communication line is locatable within the cable.

22. The system of claim 17, further including multiple power penetrators.

23. The system of claim 17, wherein the downhole equipment includes a pump operable by at least one of electrical power and hydraulic power.

24. The system of claim 23, wherein the downhole equipment includes a lubricant circulating system and a lubricant recycle system.

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