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(54) Title: COMPLETION WITH SUBSEA FEEDTHROUGH

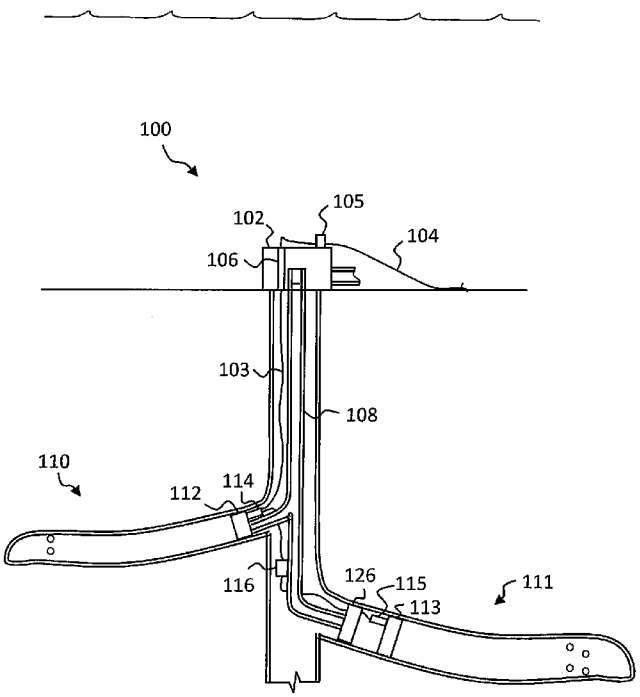


FIG. 1

(57) Abstract: Methods and systems relate to completing a subsea well having a wellhead with required pressure integrity. An electrical coupling delivers power and communication across the wellhead to completion equipment in the well. The electrical coupling may couple with a single conductive line through which power and communications are multiplexed. Multiple flow controlling tools disposed in the well couple to the conductive line with at least one energy storage device charged by the power from the conductive line for powering actuation of the tools.

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COMPLETION WITH SUBSEA FEEDTHROUGH

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0001] None.

FIELD OF THE INVENTION

[0002] Embodiments of the invention relate generally to completing a subsea well with powered devices.

BACKGROUND OF THE INVENTION

[0003] Deepwater oil and gas developments require complex wells including advanced completion capabilities, such as monitoring and remote control. Multilaterals, inaccessibility of a subsea wellhead by people and extreme pressure conditions complicate management and monitoring of the wells. Multiple separate control lines for actuation and monitoring used in other applications may not meet pressure ratings for deepwater applications or interface with current deepwater electrical standards.

[0004] Intelligent Well Interface Standardization (IWIS) provides a standard to facilitate deployment of subsea well monitoring systems. Access to well sensors with IWIS utilizes power and data multiplexed on a single conductor. Limited wattage, such as less than 100 watts, set by IWIS may not meet peak actuation requirements and is also a criteria in cable size, which if too large does not fit the standards and otherwise presents further problems with achieving desired feedthrough pressure ratings.

[0005] Traditional hydraulic systems for the actuation and monitoring also present several problems. For example, hydraulic systems lack ability to deliver pressure to longer step-out wells, which may require communication across 125 kilometers or more. Electric systems can increase current or voltage to get more power to compensate for losses over these distances.

[0006] Therefore, a need exists for systems and methods to complete a subsea well with powered devices.

BRIEF SUMMARY OF THE DISCLOSURE

[0007] For one embodiment, a subsea completion system for a well includes an electrical coupling across a wellhead located subsea. A single conductive line couples to the electrical coupling with power and communications multiplexed and passing through the line. Multiple flow controlling tools disposed in the well couple to the conductive line with at least one energy storage device charged by the power from the conductive line for powering actuation of the tools.

[0008] In one embodiment, a method of completing a well includes creating an electrical coupling across a wellhead located subsea. The method further includes coupling to the electrical coupling a single conductive line through which power and communications are multiplexed. Based on the communications sent through the conductive line, multiple flow controlling tools disposed in the well actuate and are powered by at least one energy storage device charged by the power from the conductive line.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more complete understanding of the present invention and benefits thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings.

[0010] Figure 1 is a schematic view a subsea well with completions, according to embodiments of the invention.

DETAILED DESCRIPTION

[0011] Turning now to the detailed description of the preferred arrangement or arrangements of the present invention, it should be understood that the inventive features and concepts may be manifested in other arrangements and that the scope of the invention is not limited to the embodiments described or illustrated. The scope of the invention is intended only to be limited by the scope of the claims that follow.

[0012] Embodiments of the invention relate to methods and systems for completing a subsea well, which may be at a water depth of at least 300 meters and have a wellhead to contain potential well pressures of at least 137,000 kilopascals (kPa) and operate in external sea pressures above 30,000 kPa, for example. An electrical coupling functions

under these conditions and existing standards to deliver power and communication across the wellhead to completion equipment in the well. The electrical coupling may couple with a single conductive line through which power and communications are multiplexed. Multiple flow controlling tools disposed in the well couple to the conductive line with at least one energy storage device charged by the power from the conductive line for powering actuation of the tools.

[0013] Figure 1 illustrates a well 100 drilled in a formation below sea and having a wellhead 102 disposed on a seabed. The wellhead 102 includes an electrical coupling 106 providing an electricity carrying pathway penetrating across the wellhead 102. The electrical coupling couples a control line, which may include a single conductive line 103, disposed in the well 100 with an umbilical line 104 underwater. The umbilical line 104 ties back to other subsea, floating and/or land based equipment providing electricity and used for monitoring and control of the well 100.

[0014] In some embodiments, the electrical coupling 106 includes an inductive coupling. The inductive coupling transmits electricity across the wellhead 102 without relying on use of feedthrough electrical contacts to penetrate pressure containing components of the wellhead 102. The electrical coupling 106 thus may operate without a physical penetration through the wellhead 102.

[0015] For some embodiments, the electrical coupling 106 includes a penetrating feedthrough and facilitates maintaining pressure integrity of the wellhead 102 due to limited number of such penetrations. For example, the electrical coupling 106 may form a single and only electricity carrying pathway penetrating across the wellhead 102 for control and communication with all completion equipment in the well 100. While the inductive coupling utilizes alternating current, alternating or direct current may pass through the electrical coupling 106 if electrical contact based. Power converters may change electrical energy between direct and alternating as desired at any point along an electrical system described herein.

[0016] The electrical system may comply with Intelligent Well Interface Standardization (IWIS). For example, the electrical coupling 106 may include a subsea interface in compliance with IWIS for use of an IWIS based module 105, such as a subsea electronics module (SEM) or a subsea control module (SCM). Power supply

through the electrical coupling 106 may also not exceed 100 watts or 500 watts in some embodiments.

[0017] From the wellhead 102, the conductive line 103 extends down the well 100 in an annulus surrounding production tubing 108. Using the conductive line 103 for both power and communication to more than one tool also limits feedthroughs across packers within the annulus in the well 100. A single feedthrough for each of the packers instead of multiple feedthroughs for each may facilitate achieving desired pressure ratings for the packers similar to the wellhead 102.

[0018] By way of example, the well 100 includes a first lateral bore 110 and a second lateral bore 111 through which hydrocarbon production fluids enter from a surrounding reservoir. The lateral bores 110, 111 include completion equipment, which may be any tools, such as first flow controlling tool 112 and second flow controlling tool 113, requiring electrical power for mechanical actuation or other physical deployment. Examples of the flow controlling tools 112, 113 include valves (e.g., a ball valve, a flapper valve, a sliding sleeve valve or an annular control valve), chokes (e.g., a tubing flow choke or an annular choke), packers and a disappearing plug.

[0019] The first flow controlling tool 112 adjusts inflow into the production tubing 108 in a main bore from the first lateral bore 110. A first energy storage device 114, such as a battery or accumulator, couples to the conductive line 103 and is charged for powering the first flow controlling tool 112. The conductive line 103 also provides command signals for controlling actuation of the first flow controlling tool 112 since the power and communications are multiplexed on the conductive line 103.

[0020] Since both the tools 112, 113 couple to the conductive line 103, a separate command signal sent through the conductive line 103 functions the second flow controlling tool 113 to adjust inflow into the production tubing 108 in the main bore from the second lateral 111. The second flow controlling tool 113 may share power from the first energy storage device 114 or utilize a second energy storage device 115, which is also coupled to the conductive line 103 and may be disposed proximate the second flow controlling tool 113. Current and voltage limits able to be passed through the conductive line 103 may lack ability to operate the tools 112, 113 without the energy storage devices 114, 115.

[0021] One or more instruments, such as a sensor 116, in the well 100 may also couple to the conductive line 103. The sensor 116 with lower power demand than the tools 112, 113 may operate straight from electrical transmission through the conductive line 103. For some embodiments, the sensor 116 turns off and is only turned on when desired to make a measurement so that the sensor 116 is not using continuous power all the time. The sensor 116 conveys data about a parameter, such as density, pressure, temperature, flow and/or water cut, back through the conductive line 103 to the equipment disposed outside of the well 100. In some embodiments, actuation of the tools 112, 113 depends on the data from the sensor 116 and may be automated to operate in response to the data.

[0022] In some embodiments, the conductive line 103 couples to the second flow controlling tool 113 and the second energy storage device 115 through a lateral inductive coupling 126 for the second lateral bore 111. Similar to the electrical coupling 106 at the wellhead 102, a junction between the main bore and the second lateral bore 111 may benefit from the lateral inductive coupling 126 maintaining pressure integrity without use of physical electrical contacts. The lateral inductive coupling 126 establishes power and communication with the second flow controlling tool 113 and the second energy storage device 115 disposed in the second lateral bore 111 without a physical penetration through the junction. The lateral inductive coupling 126 may form an integral part of tubing at the junction.

[0023] Based on the foregoing, a method of completing the well 100 includes creating the electrical coupling 106 across the wellhead 102 subsea. The method further includes coupling to the electrical coupling 106 the single conductive line 103 through which power and communications are multiplexed. Actuating the flow controlling tools 112, 113 disposed in the well 100 occurs based on the communications sent through the conductive line 103 with the tools 112, 113 powered by the energy storage devices 114, 115 charged by the power from the conductive line 103.

[0024] The tools 112, 113, the sensor 116 and all other completion equipment in the well 100 may couple to the single conductive line 103 for communicating with equipment outside the well 100 and, with the energy storage devices 114, 115, receiving power for actuation. Therefore, the well 100 may utilize the single conductive line 103

alone and have no other hydraulic, electric or optical control lines. However, some embodiments may use additional control lines or multiple conductive lines, such as for backup purposes, with aspects of the invention to still achieve benefits described herein.

[0025] In closing, it should be noted that the discussion of any reference is not an admission that it is prior art to the present invention, especially any reference that may have a publication date after the priority date of this application. At the same time, each and every claim below is hereby incorporated into this detailed description or specification as additional embodiments of the present invention.

[0026] Although the systems and processes described herein have been described in detail, it should be understood that various changes, substitutions, and alterations can be made without departing from the spirit and scope of the invention as defined by the following claims. Those skilled in the art may be able to study the preferred embodiments and identify other ways to practice the invention that are not exactly as described herein. It is the intent of the inventors that variations and equivalents of the invention are within the scope of the claims while the description, abstract and drawings are not to be used to limit the scope of the invention. The invention is specifically intended to be as broad as the claims below and their equivalents.

CLAIMS

1. A subsea completion system for a well, comprising:

an electrical coupling across a wellhead located subsea;

a single conductive line coupled to the electrical coupling and through which power and communications are multiplexed;

multiple flow controlling tools disposed in the well coupled to the conductive line; and

at least one energy storage device charged by the power from the conductive line for powering actuation of the tools.

2. The subsea completion system according to claim 1, wherein the energy storage device includes a battery.

3. The subsea completion system according to claim 1, wherein the electrical coupling includes an inductive coupling.

4. The subsea completion system according to claim 1, wherein the electrical coupling is limited to less than 100 watt power supply.

5. The subsea completion system according to claim 1, wherein the electrical coupling forms a single and only electricity carrying pathway penetrating across the wellhead for control of all completion equipment in the well.

6. The subsea completion system according to claim 1, wherein the electrical coupling includes a subsea interface compliant with Intelligent Well Interface Standardization (IWIS).

7. The subsea completion system according to claim 1, wherein the conductive line is coupled in the well to an inductive coupling for a lateral to power one of the tools in the lateral.

8. The subsea completion system according to claim 1, wherein the electrical coupling and a lateral connection include inductive couplings.

9. The subsea completion system according to claim 1, further comprising at least one sensor coupled to the conductive line for transfer of data through the wellhead.

10. The subsea completion system according to claim 1, wherein the tools include at least one of a valve, a choke, a packer and a disappearing plug.

11. A method of completing a well, comprising:

creating an electrical coupling across a wellhead located subsea;

coupling to the electrical coupling a single conductive line through which power and communications are multiplexed; and

actuating based on the communications sent through the conductive line multiple flow controlling tools disposed in the well and powered by at least one energy storage device charged by the power from the conductive line.

12. The method according to claim 11, wherein the energy storage device includes a battery.

13. The method according to claim 11, wherein the electrical coupling includes an inductive coupling.

14. The method according to claim 11, wherein power supply through the electrical coupling is limited to less than 100 watts.

15. The method according to claim 11, wherein the electrical coupling forms a single and only electricity carrying pathway penetrating across the wellhead for control of all completion equipment in the well.

16. The method according to claim 11, wherein the electrical coupling includes a subsea interface compliant with Intelligent Well Interface Standardization (IWIS).

17. The method according to claim 11, wherein the conductive line is coupled in the well to an inductive coupling for a lateral to power one of the tools in the lateral.

18. The method according to claim 11, wherein the electrical coupling and a lateral connection include inductive couplings.

19. The method according to claim 11, wherein the tools include at least one of a valve, a choke, a packer and a disappearing plug.

20. The method according to claim 11, further comprising at least one sensor coupled to the conductive line for transfer of data through the wellhead.

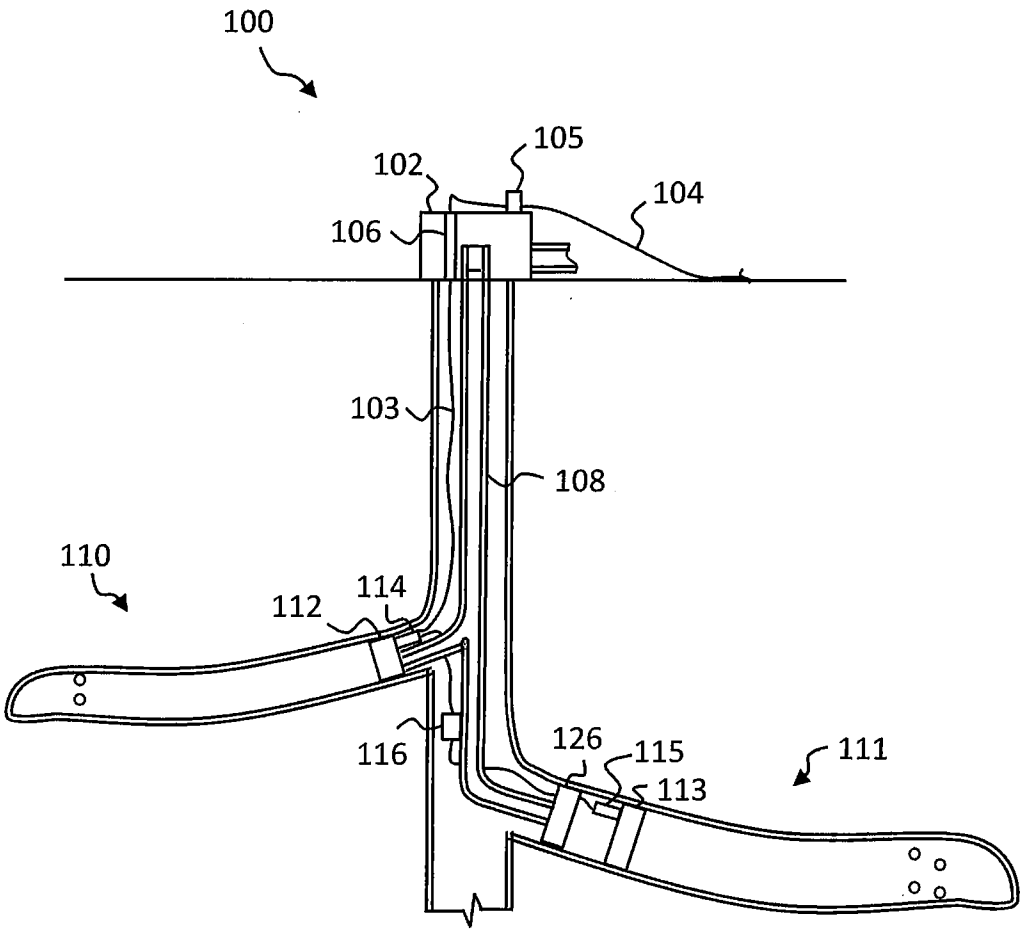


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/040600

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 47/12 (2015.01)
CPC - E21B 47/12 (2015.04)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - see last page
USPC -166/243, 250, 319, 336, 373; 340/853.3, 856.3; 700/3, 82, 275, 281, 282

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - E21B 7/00, 7/12, 7/14, 23/00, 23/04, 33/0355, 33/12, 33/126, 34/045, 34/10, 34/16, 41/00, 43/12, 43/14, 47/12; G01V 3/00; H04B 3/54; H04J 15/00; H04L 67/12 (2015.04) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, Google Scholar, ProQuest.
Search terms used: subsea, water, ocean, well, borehole, completion, conduct, power, energy, storage, battery, communication, multiplex, mux.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,052,703 A (COLLINS, SR. et al.) 04 October 1977 (04.10.1977) entire document	1-20
Y	US 6,257,332 B1 (VIDRINE et al.) 10 July 2001 (10.07.2001) entire document	1-20
Y	US 2014/0033842 A1 (MORIN et al.) 06 February 2014 (06.02.2014) entire document	4,14
Y	US 2011/0001483 A1 (DAVEY) 06 January 2011 (06.01.2011) entire document	6,16
A	US 7,380,609 B2 (PAGE et al.) 03 June 2008 (03.06.2008) entire document	1-20
A	US 2008/0217022 A1 (DEANS) 11 September 2008 (11.09.2008) entire document	1-20
A	US 7,114,571 B2 (GATHERAR et al.) 03 October 2006 (03.10.2006) entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 September 2015	08 OCT 2015
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2015/040600

Continuation of Box B Fields Searched

IPC (8) Class/Subclass(es): E21B 7/00, 7/12, 7/14, 23/00, 33/035, 33/038, 23/04, 33/12, 33/126, 34/04, 34/10, 34/06, 34/16, 41/00, 43/12, 43/12, 43/14, 47/12; G01V 3/00; H04B 3/54; H04J 15/00; H04L 67/12 (2015.01)