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(54) **SUBSEA CONTROL SYSTEM**

(57) It is described a control system and a method for controlling a subsea device (150; 250; 350), wherein the control system comprises:
• a subsea control circuit (140; 240; 340) for operating the subsea device (150; 250; 350);
• a subsea energy storage (130; 230; 330) for providing energy to the subsea control circuit (140; 240; 340);
• a signal transmitter and a signal receiver arranged to provide signals to the subsea control circuit (140; 240; 340); and
• a flexible production riser (120; 220; 320) comprising:
- an outer sheath;
- a bore; and
- an energy supply line (121; 221; 321) embedded between said outer sheath and said bore and suitable for providing energy to the subsea energy storage (130; 230; 330).

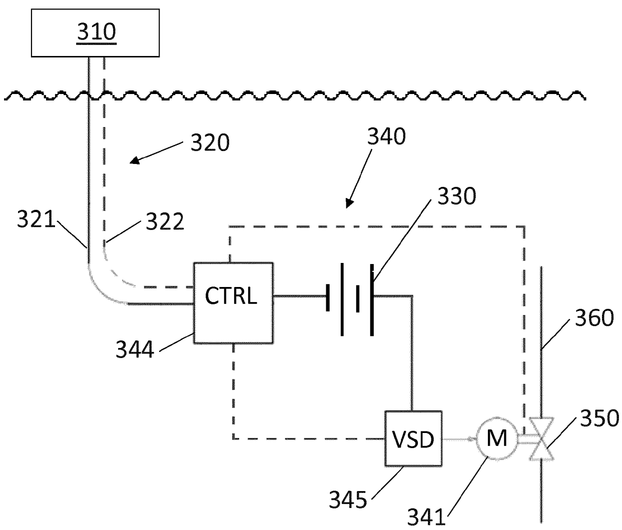

Fig. 3

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Description

Technical Field

[0001] The present invention relates to a system and method for controlling a subsea device, such as a subsea isolation valve.

Background of the Invention

[0002] Subsea devices such as subsea isolation valves (SSIV), isolation valves for gas lift and isolation valves for MEG injection are commonly used in the interface between the wet end of a riser and a flowline. SSIVs are used with risers, in particular dynamic risers, for the purpose of protecting a platform in case of fire, acting as a safety valve preventing gas from the export line from fueling the fire. From a safety analysis perspective SSIVs are not always legally required; however, operators are willing to protect the platform and the personnel at considerable cost. This is part of the strategy for prevention of major hazards.

[0003] SSIVs are traditionally controlled by direct hydraulic operation from a topside hydraulic power unit (HPU) via a dedicated control riser. The control riser may have one or several hydraulic conduits, often also electrical cables for instrumentation, mostly valve position but also pressure.

[0004] A drawback with the traditional control system is the response time. This is a function of conduit size, conduit elasticity, fluid viscosity and the force provided by the emergency shutdown (ESD) return spring.

[0005] Another drawback with the traditional control system is that a dedicated control riser is costly and occupies a riser slot. Dedicated control risers have usually been equipped with one or several hydraulic conduits of ¾ inch ID to achieve required response to emergency shut down (ESD).

[0006] Slug detectors (pressure sensor) are occasionally installed in the interface between a flowline and a riser to detect formation and size of liquid slugs. Large terrain slugs formed in a riser (typically lazy wave) threaten stability of the topside process by injecting large liquid slugs into the separator. A combination of a dynamic topside choke and a subsea slug detector can be used to manage slugs dynamically. However, a dedicated control riser for only the purpose of providing slug detection is usually prohibitively costly.

Summary of the Invention

[0007] An objective of the present invention is to provide an improved system for controlling subsea units (such as SSIVs, slug detectors, isolation valves for gas lift and isolation valves for MEG injection) which solves one or more of the identified drawbacks.

[0008] Said objective is fully or partly achieved by a control system and a method according to the independent claims. Preferred embodiments are set forth in the dependent claims.

[0009] According to a first aspect, the invention relates to a subsea control system for controlling a subsea device, wherein the control system comprises: a subsea control circuit for operating the subsea device, a subsea energy storage for providing energy to the subsea control circuit, a signal transmitter and a signal receiver arranged to provide signals to the subsea control circuit, and a flexible production riser. The flexible production riser comprises: an outer sheath, a bore, and an energy supply line embedded between said outer sheath and bore and suitable for providing energy to the subsea energy storage.

[0010] It is thus achieved a control system with the benefit of being able to satisfy the required response time and the required amount of energy for operating the subsea device while being independent of the size of the energy supply line.

[0011] An advantage of this control system is that the response time for operating the subsea device is reduced compared to previous control systems.

[0012] An advantage of this control system being independent of the size of the energy supply line is that it allows the inner diameter (ID) of the energy supply line to be reduced compared to previous energy supply lines.

[0013] An advantage of this control system having an energy supply line with a reduced ID is that it is less exposed to fatigue than larger conduits.

[0014] An advantage of this control system having an energy supply line with a reduced ID is that it may be embedded in a production riser in a cost-efficient manner.

[0015] An advantage of this control system having embedded the energy supply line in the production riser is that the cost of a separate energy supply riser is eliminated.

[0016] An advantage of this control system having embedded the energy supply line in the production riser is that a riser slot is made available.

[0017] The flexible production riser may comprise a signal line embedded between the outer sheath and the bore for providing communication between the signal transmitter and the signal receiver, wherein the signal line optionally may be the energy supply line.

[0018] It is thus achieved a control system which in addition to communicating wireless by means of radio or acoustic signals between the signal transmitter and the signal receiver may also communicate by cable by means of hydraulic, electric, optical, pneumatic, or similar signals.

[0019] An advantage of this control system having embedded the signal line in the production riser is that the need for a separate signal line is eliminated. The signal line may be a conduit similar to the energy supply line, and thus be embedded in the production riser in a cost-efficient manner.

[0020] An advantage of this control system having combined the signal line and the energy supply line is that one less line is required, or a line is made available.

[0021] The signal transmitter and the signal receiver may be arranged to provide signals from the subsea control circuit.

[0022] It is thus achieved a control system with two-way communication between topside and subsea.

[0023] An advantage of this control system having two-way communication is that in addition to commanding operations of the subsea device, the control system may monitor the status of the control circuit and in particular the status of the subsea device.

[0024] The subsea device may be a subsea isolation valve, an isolation valve for gas lift or an isolation valve for MEG injection.

[0025] The energy supply line may be a hydraulic line with an inner diameter of less than 10 mm, preferably between 4-8 mm and more preferably 5-6 mm.

[0026] It is thus achieved a control system in which the energy supply line may be embedded in the production riser in a cost-efficient manner.

[0027] The subsea energy storage may be a hydraulic accumulator.

[0028] The subsea control circuit may comprise: a directional control valve, an actuator, and an outlet to sea. Wherein the directional control valve is in fluid communication with the energy storage, the actuator and the outlet to sea. Wherein the directional control valve comprises the signal receiver and is arranged to control the fluid flow between the energy storage and the actuator and the fluid flow between the actuator and the outlet to sea. Wherein the actuator is arranged to drive the subsea device.

[0029] The signal line may be a hydraulic line.

[0030] It is thus achieved a control system which is hydraulically powered, but may be controlled by means of hydraulic, electric, optic, pneumatic, acoustic, radio or similar signals.

[0031] The energy supply line may be an electrical AC cable or an electrical DC cable with an outer diameter of less than 9 mm, preferably between 3-7 mm and more preferably 4-5 mm.

[0032] It is thus achieved a control system with an energy supply line which may be housed by the conduits embedded in the production riser.

[0033] The electrical AC/DC cable may be a single-phase conductor and the flexible riser may have an electrical conductive armor which serves as a return conductor.

[0034] It is thus achieved a control system with a production riser in which the cross-section of the energy supply line may be reduced or where more energy can be supplied without increasing the cross-section.

[0035] An advantage of the energy supply line with a reduced cross-section is that it is less stiff and that it frees up space in the production riser.

[0036] The subsea energy storage may be a battery, a capacitor or a combination thereof.

[0037] The subsea control circuit comprises: a digital control unit, an electric actuator, and variable speed drive. Wherein the electrical control unit is in electrical communication with the energy supply line and in electrical communication with the energy storage. Wherein the variable speed drive is in electrical communication with the energy storage and arranged to drive the electrical actuator. Wherein the electrical actuator is arranged to drive the subsea device. Wherein the electrical control unit comprises the signal receiver and arranged to transmit signals to the variable speed drive.

[0038] The signal line may be an electrical or optical line.

[0039] It is thus achieved an all-electric control system.

[0040] An advantage of this control system is that it is suitable for redundancy arrangements which may enhance the safety integrity level (SIL) rating radically.

[0041] According to a second aspect, the invention relates to a method for controlling a subsea device by means of a control system, wherein the control system comprises: a subsea control circuit for operating the subsea device, a subsea energy storage for providing energy to the subsea control circuit, a signal transmitter and a signal receiver for providing signals to the subsea control circuit, and a flexible production riser. The flexible production riser may comprise: an outer sheath, a bore, and an energy supply line embedded between said outer sheath and bore and suitable for providing energy to the subsea energy storage. Wherein the method comprises the steps of: charging the subsea energy storage by means of the energy supply line at a rate of 5-30 % of the subsea energy storage capacity per hour, preferably 10-25 %, more preferably 10-20 %; communicating with the subsea control circuit by means of the signal transmitter and the signal receiver; and operating the subsea device by means of the control circuit.

[0042] It is thus achieved a method with reduced response time for operating the subsea device.

[0043] According to a third aspect, the invention relates to a system for controlling a subsea slug detector, wherein the control system comprises: a subsea control circuit for operating the subsea slug detector; and a flexible production riser. The flexible production riser comprises: an outer sheath, a bore, an energy supply line embedded between said outer sheath and bore and suitable for providing energy to the subsea slug detector, and a signal line for transmitting a signal to and from the subsea slug detector. Wherein the energy supply line optionally may be the signal line.

[0044] It is achieved a control system in which slug detection can be provided without the need of a dedicated control riser for the slug detector.

Brief Description of Drawings

[0045] The invention will now be described with reference to the exemplifying nonlimiting embodiments shown in the accompanying drawings, wherein:

Fig. 1 shows a schematic of a fully hydraulic control system;

Fig. 2 shows a schematic of an at least partly hydraulic control system; and

Fig. 3 shows a schematic of an all-electric control system.

Detailed Description

[0046] Fig. 1 shows the schematic of a fully hydraulic control system. This control system is used to control a subsea device 150 from topside 110.

[0047] In the embodiment of Fig. 1, the subsea device 150 is a valve. Relevant valve usage may be subsea isolation valves (SSIV), isolation valves for gas lift, isolation valves for MEG injection or similar. The subsea device 150, in this case the valve, is operated by a control circuit 140 which is also located subsea, preferably as close to the subsea device 150 as possible. The control circuit 140 comprise a plurality of interconnected components arranged to operate the subsea device 150. An energy storage 130 is also located subsea, preferably as close to the subsea control circuit 140 as possible or even more preferably incorporated in the subsea control circuit 140. This subsea energy storage 130 provides energy to the subsea control circuit 140 such that the subsea control circuit 140 may operate the subsea device 150. In the embodiment of Fig. 1, the subsea energy storage 130 is a hydraulic accumulator. Several hydraulic accumulators may be used in parallel. Energy is provided to the subsea energy storage 130 through an energy supply line 121, i.e. a hydraulic energy supply line. The subsea control circuit 140 is controlled from topside 110 by means of a signal transmitter located topside 110 which communicates with a signal receiver located subsea, part of the directional control valve (DCV) 142.

[0048] In a fully hydraulic control system, the signal is in the form of a hydraulic pressure change. The transmitter and receiver are then communicating through a signal line 122, i.e. a hydraulic line. This hydraulic signal line and the hydraulic energy supply line are in these cases separate lines. Prior art control systems have a direct operation of the subsea device 150, i.e. one or several energy supply lines 121 are connected directly to the subsea device 150 and no signal lines 122 are used.

[0049] A flexible production riser 120 extends from topside 110 to the subsea control circuit 140. Such a flexible production riser 120 typically has a bore and an outer sheath. The signal line 122 and/or the energy supply line 121 may be embedded between said outer sheath and said bore.

[0050] Due to the subsea energy storage 130, the energy supply line 121 may have a smaller ID than conventional energy supply lines 121. The energy supply line 121 will gradually build up the energy level in the subsea energy storage 130. The subsea energy storage 130 will have the capacity to store a sufficient amount of energy to operate the subsea device 150. The subsea energy storage 130 may also have the capacity to supply energy to the subsea device 150 at a rate enabling it to operate within a required response time, e.g. in the event of an emergency shut down (ESD). In this way the energy supply line 121 may supply energy at a lower rate than what's required to operate the subsea device 150, i.e. the response time of the subsea device 150 is no longer related to the supply line 121 size. The subsea device 150 in the form of a valve may be closed by the biasing spring illustrated inside the actuator when the applied pressure in the actuator is bled off through the outlet to sea 143.

[0051] As an alternative to the hydraulic accumulator, the subsea energy storage 130 may be a pneumatic accumulator. This requires that the energy supply line 121 is a pneumatic energy supply line 121.

[0052] The energy supply line 121 may be a conduit with an inner diameter (ID) less than 10 mm. The ID could preferably be even smaller, in the range of 4-8 mm or 5-6 mm. Such small conduits will have little impact on the riser production cost.

[0053] The charging rate of the subsea energy storage 130 in the form of an accumulator depends on the ID of the energy supply line 121 in the form of a hydraulic conduit. Said charging rate will increase with a larger ID. The charging rate of the subsea energy storage 130 will also depend on the capacity of the subsea energy storage 130. The capacity of the subsea energy storage 130 is scaled depending on the subsea device 150. Even though a high charge rate may be desirable, the ID of the energy supply line 121 should not be compromised. 10-15 % of the subsea energy storage 130 capacity per hour or 15-20% of the subsea energy storage 130 capacity per hour may be typical charging rates.

[0054] Typically, the size and/or number of accumulators is selected to provide sufficient energy to close and open the valve at least one time, preferably 5-10 times, providing sufficient flexibility in the use of the subsea device 150 considering that it may take hours to recharge the accumulator through the energy supply line 121.

[0055] The hydraulic subsea control circuit 140 in the embodiment of Fig. 1 comprises a hydraulically piloted directional control valve (DCV), an actuator and an outlet to sea 143.

[0056] The actuator is in this embodiment hydraulically operated and arranged to drive the subsea device 150. The actuator may be provided with a spring biasing the actuator to a default position, e.g. to provide fail safe close functionality.

[0057] The DCV 142 has a 3/2 configuration, meaning that it has three inlet/outlet ports and two valve positions. The firs port is in fluid communication with the subsea energy storage 130, the second port is in fluid communication with the actuator and the third port is in fluid communication with the outlet to sea 143. The first valve position connects the subsea energy storage 130 and the actuator while shutting off the outlet to sea 143. The second valve position connects the actuator and the outlet to sea 143 while shutting off the subsea energy storage 130. The DCV 142 may comprise the signal receiver. When the signal receiver comprised by the DCV 142 receives a signal from the signal transmitter, it may be arranged to operate the DCV 142 from the first valve position to the second valve position or *vice versa.* The subsea storage 130, the DCV 142, the actuator and the outlet to sea 143 may be interconnected by means of a conduit with a larger ID than the energy supply line 121. The larger the ID of said conduits are, the shorter response time for operating the subsea device 150 may be achieved.

[0058] In the first valve position, wherein the subsea energy storage 130 and the actuator 141 are connected, the actuator 141 will receive energy in the form of hydraulic pressure from the subsea energy storage 130. Said hydraulic pressure will cause the actuator 141 to operate the subsea device 150, e.g. open/close valve. In the second valve position, wherein the actuator and the outlet to sea 143 are connected, the applied hydraulic pressure will be vented through the outlet to sea 143. Due to the loss of pressure, the actuator 141 will be returned to its default position by the spring; thus, operating the subsea device 150 accordingly.

[0059] The DCV 142 will typically have a default position in which the subsea energy storage is disconnected from the actuator.

[0060] The outlet to sea 143 is arranged to drain the hydraulic pressure from the actuator 141 within the response requirements for emergency shut down (ESD) closure time. Response time in this embodiment relates to the DCV 142 shifting from one valve position to another valve position, a bleed back of a volume of 2-4 cm^3, which is in the seconds domain. Traditionally the response time relates to the bleed back of the volume of the actuator 141, typically 10 liters for a 10 inch valve and 25 liters for a 40 inch valve (1 inch equals 25,4 mm). This volume must be returned through the energy supply line 121, in which case 2-3 minutes for ESD is often accepted but can be difficult to achieve with lines of a reasonable size.

[0061] Fig. 2 shows the schematic of a partly hydraulic control system. This control system is also used to control a subsea device 250 from topside 210.

[0062] The embodiment of Fig. 2 is different from the embodiment of Fig. 1 in that it has a different type of communication between the signal transmitter and the signal receiver. Furthermore, the embodiment of Fig. 2 has a different type of DCV 242 than the embodiment of Fig. 1.

[0063] In partly hydraulic systems, the signal may be in the form of a radio signal, an electrical signal, an optical signal or an acoustic signal. The transmitter and receiver may then communicate wirelessly or through a signal line 222, e.g. an electric line. The signal line 222 may be embedded between the outer sheath and the bore of the flexible production riser 220. Such signal lines 222 and the hydraulic energy supply line 221 are in these cases separate lines.

[0064] Similar conduits as those described as energy supply lines 121 in Fig. 1 may be used to house the signal line 222.

[0065] The DCV 242 of Fig. 2 has a 4/2 configuration, meaning that it has four inlet/outlet ports and two valve positions. The firs port is in fluid communication with the subsea energy storage 230, the second port is in fluid communication with a first side of the actuator 241, the third port is in fluid communication with a second side of the actuator 241 and the fourth port is in fluid communication with the outlet to sea 243. The first valve position connects the subsea energy storage 230 with the first side of the actuator 241 while connecting the second side of the actuator 241 with the return to sea 243. The second valve position connects the subsea energy storage 230 with the second side of the actuator 241 while connecting the first side of the actuator 241 with the outlet to sea 243. In this way the accumulator energy is used to operate the actuator 241 in both directions, i.e. the actuator 241 is bidirectional, making the biasing spring superfluous. The bidirectional actuator 241 (4/2 configuration) may have a shorter response time than the 3/2 configuration. The bidirectional actuators 241 may be set up to have fail-to-last position functionality.

[0066] Fig. 3 shows the schematic of a digital control system. This control system is also used to control a subsea device 350 from topside 310.

[0067] In the embodiment of Fig. 3, the subsea device 350 is a valve. Relevant valve usage may be subsea isolation valves (SSIV), isolation valves for gas lift, isolation valves for MEG injection or similar. The subsea device 350, in this case the valve, is operated by a digital control circuit 340 which is also located subsea, preferably as close to the subsea device 340 as possible. An energy storage 330 is also located subsea, preferably as close to the control circuit 340 as possible or even more preferably incorporated in the control circuit 340. This subsea energy storage 330 provides energy to the control system such that the control system may operate the subsea device 350. In the embodiment of Fig. 3, the subsea energy storage 330 is a battery, e.g. a lithium-ion battery. Several batteries may be used in series or in parallel. Energy is provided to the subsea energy storage 330 through an energy supply line 321, i.e. an electric energy supply line. The subsea control circuit 340 is controlled from topside 310 by means of a signal transmitter located topside 310 which communicates with a signal receiver located subsea.

[0068] In digital systems, the signal may be in the form of a radio signal, electrical signal, optical signal or acoustic signal. The transmitter and receiver may then communicate wirelessly or through a signal line 322, e.g. an electric line.

[0069] A flexible production riser 320 extends from topside to the subsea control circuit. Such a flexible production riser 320 typically has a bore and an outer sheath. The signal line 322 and/or the energy supply line 321 may be embedded between said outer sheath and said bore.

[0070] Due to the subsea energy storage 330, the energy supply line 321 may have a smaller ID than conventional energy supply lines 321. The energy supply line 321 will gradually charge the energy level in the subsea energy storage 330. The subsea energy storage 330 will have the capacity to store a sufficient amount of energy to operate the subsea device 350. The subsea energy storage 330 may also have the capacity to supply energy to the subsea device 350 at a rate enabling it to operate within a required response time, e.g. in the event of an emergency shut down (ESD). In this way the energy supply line 321 may supply energy at a lower rate than what's required to operate the subsea device 350, i.e. the response time of the subsea device 350 is no longer related to the supply line 321 size.

[0071] Similar conduits as those described as energy supply lines 121 in Fig. 1 may be embedded in the flexible production riser 320 to house the signal line 322 and/or electrical energy supply line 321. This energy supply line 321 may be a cable with an outer diameter (OD) less than 9 mm. The OD could preferably be even smaller, in the range of 3-7 mm or 4-5 mm. Such small cables will have little impact on the riser production cost.

[0072] The charging rate of the subsea energy storage 330 in the form of a battery depends on the cross-section of the energy supply line 321 in the form of an electrical cable. Said charging rate will increase with a larger cross-section. The charging rate of the subsea energy storage 330 will also depend on the capacity of the subsea energy storage 330. The capacity of the subsea energy storage 330 is scaled depending on the subsea device 350. Even though a high charge rate may be desirable, the cross-section (and thus the outer diameter) of the energy supply line 321 should not be compromised. 10-15 % of the subsea energy storage 330 capacity per hour or 15-20% of the subsea energy storage 330 capacity per hour may be typical charging rates.

[0073] The electrical signal line 322 and the energy supply line 321 may be the same line. An electrical control signal may be run into the power line, e.g. as a 100 kHz signal superimposed on the regular 60 Hz AC power feed.

[0074] The flexible production riser 320 may comprise a pipe armor. Energy may be delivered by a single electrically isolated line with current return via said pipe armor.

[0075] The electrical energy supply line 321 may be an electrical AC cable or an electrical DC cable.

[0076] As an alternative to battery, the subsea energy storage 330 may be a capacitor, or it may even be a combination of a battery and a capacitor.

[0077] The digital subsea control circuit 340 in the embodiment of Fig. 3 comprises a digital control unit 344, a variable speed drive (VSD) 345 and an actuator 341 in the form of a motor.

[0078] In the embodiment of Fig. 3, energy is supplied through the energy supply line 321 in the flexible production riser 320. The energy supply line 321 terminates in the digital control unit 344 which route the energy to the subsea energy storage 330, in this case a battery, a capacitor or a combination thereof. Some of the energy supplied by the energy supply line 321 is used to power the digital control unit 344. The digital control unit 344 also comprise the signal receiver which may receive signals from the topside signal transmitter, either wirelessly or by means of the signal line 322. If the signal line 322 and the energy supply line 321 is the same line, the digital control unit 344 will split the energy from the signal.

[0079] Alternatively, the energy supply line 321 may terminate in the subsea energy storage 330. The digital control unit 344 should then be connected to and powered by the subsea energy storage 330. The digital control unit 344 should still comprise the signal receiver.

[0080] The digital control unit 340 may comprise a signal transmitter which communicates with a signal receiver located topside 310. An example of information sent from the digital control unit 340 to topside 310 may be the status of or information from the subsea device 350, e.g. valve status, pressure/temperature readings, slug detection or similar.

[0081] In order for the digital control unit 344 to transmit the status of or information from the subsea device 350, the digital control unit 344 must communicate with the subsea device 350. This may be done by means of an additional set of signal transmitter and signal receiver as already described.

[0082] The digital control unit 344 may be programmed to execute specific commands as a response to certain readings from the subsea device 350, such as open/close a valve if a triggering value is observed.

[0083] A variable speed drive (VSD) 345 is connected to and receives signals from the digital control unit 344. This may be done by means of an additional set of signal transmitter and signal receiver as already described. The VSD 345 is connected to and receives energy from the subsea energy storage 330. On signal from the digital control unit 344, the VSD 345 will transform received electric energy into 3-phase current and rout it to a connected electric actuator 341, in this case a rotary electric motor.

[0084] The electric actuator 341 is connected to and drives the subsea device 350. Status of and readings from the electric actuator 341 may also be communicated to the digital control unit 344. This may be done by means of an additional set of signal transmitter and signal receiver as already described.

[0085] In cases where the subsea device 350 is a slug detector, the control system may not need a subsea energy storage 330. Unlike valves, a slug detector doesn't require periods of increased energy supply and the steady supply of energy required by the slug detector may be a provided by the above-mentioned energy supply line 321. Operation of a slug detector requires simply a 4-20 mA circuit and thus a marginal cross section of copper. A twisted pair embedded in a tube for protection would be suitable. Coax is effective in cross section and signal immunity but difficult to terminate and for that reason has never been used extensively in the subsea industry.

[0086] These control systems may also have several subsea components, e.g. a slug detector and a SSIV.

Reference list:

[0087]

110; 210; 310 - topside
120; 220; 320 - flexible production riser

121; 221; 321 - energy supply line
122; 222; 322 - signal line

130; 230; 330 - subsea energy storage
140; 240; 340 - subsea control circuit

141; 241; 341 - actuator
142; 242 - (hydraulic pilot) directional control valve
143; 243 - outlet to sea
344 - digital control unit
345 - variable speed drive

150; 250; 350 - subsea device
160; 260; 360 - flowline

Claims

1. A control system for controlling a subsea device (150; 250; 350), wherein the control system comprises:

    a. a subsea control circuit (140; 240; 340) for operating the subsea device (150; 250; 350);
    b. a subsea energy storage (130; 230; 330) for providing energy to the subsea control circuit (140; 240; 340);
    c. a signal transmitter and a signal receiver arranged to provide signals to the subsea control circuit (140; 240; 340); and
    d. a flexible production riser (120; 220; 320) comprising:

        - an outer sheath;
        - a bore; and
        - an energy supply line (121; 221; 321) embedded between said outer sheath and said bore and suitable for providing energy to the subsea energy storage (130; 230; 330).

2. The control system according to claim 1, wherein the flexible production riser (120; 220; 320) comprises a signal line (122; 222; 322) embedded between the outer sheath and the bore for providing communication between the signal transmitter and the signal receiver, wherein the signal line (122; 222; 322) optionally may be the energy supply line (121; 221; 321).

3. The control system according to claim 1 or 2, wherein the signal transmitter and the signal receiver is arranged to provide signals from the subsea control circuit (140; 240; 340).

4. The control system according to any one of the preceding claims, wherein the subsea device (150; 250; 350) is a subsea isolation valve, an isolation valve for gas lift or an isolation valve for MEG injection.

5. The control system according to any one of the preceding claims, wherein the energy supply line (121; 221) is a hydraulic line with an inner diameter of less than 10 mm, preferably between 4-8 mm and more preferably 5-6 mm.

6. The control system according to any one of the preceding claims, wherein the subsea energy storage (130; 230) is a hydraulic accumulator.

7. The subsea control system according to any one of the preceding claims, wherein the subsea control circuit (140; 240) comprises:

    a. a directional control valve (142; 242);
    b. an actuator (141; 241); and
    c. an outlet to sea (143; 243);

    wherein the directional control valve (142; 242) is in fluid communication with the energy storage (130; 230), the actuator (141; 241) and the outlet to sea (142; 242);
    wherein the directional control valve (141; 241) comprises the signal receiver and is arranged to control the fluid flow between the energy storage (130; 230) and the actuator (141; 241) and the fluid flow between the actuator (141; 241) and the outlet to sea (143; 243); and
    wherein the actuator (141; 241) is arranged to drive the subsea device (150; 250).

8. The control system according to any one of claims 1 -3, wherein the energy supply line (321) is an electrical AC cable or an electrical DC cable with an outer diameter of less than 9 mm, preferably between 3-7 mm and more preferably 4-5 mm.

9. The control system according to claim 8, wherein the electrical AC/DC cable is a single-phase

conductor and the flexible riser (320) has an electrical conductive armor which serves as a return conductor.

10. The control system according to any one of claims 1-3 and 8-9,
wherein the subsea energy storage (330) is a battery, a capacitor or a combination thereof.

11. The subsea control system according to any one of claims 1-4 and 8-10,
wherein the subsea control circuit (340) comprises:

a. digital control unit (344);
b. an electric actuator (341); and
c. variable speed drive (345);

wherein the digital control unit (344) is in electrical communication with the energy supply line (321) and in electrical communication with the energy storage (330);
wherein the variable speed drive (345) is in electrical communication with the energy storage (330) and arranged to drive the electrical actuator (341); wherein the electrical actuator (341) is arranged to drive the subsea device (350); and
wherein the digital control unit (344) comprises the signal receiver and arranged to transmit signals to the variable speed drive (345).

12. The control system according to any one of the preceding claims,
wherein the signal line (222; 322) is an electrical or optical line.

13. The control system according to claims 1-7,
wherein the signal line (122) is a hydraulic line.

14. A method for controlling a subsea device (150; 250; 350) by means of a control system, wherein the control system comprises:

a. a subsea control circuit (140; 240; 340) for operating the subsea device (150; 250; 350);
b. a subsea energy storage (130; 230; 330) for providing energy to the subsea control circuit (140; 240; 340);
c. a signal transmitter and a signal receiver for providing signals to the subsea control circuit (140; 240; 340); and
d. a flexible production riser (120; 220; 320) comprising:

- an outer sheath;
- a bore; and
- an energy supply line (121; 221; 321) embedded between said outer sheath and said bore and suitable for providing energy to the subsea energy storage (130; 230; 330);

wherein the method comprises the steps of:

a. charging the subsea energy storage (130; 230; 330) by means of the energy supply line (121; 222; 322) at a rate of 5-30 % of the subsea energy storage capacity per hour, preferably 10-25 %, more preferably 10-20 %;
b. communicating with the subsea control circuit (140; 240; 340) by means of the signal transmitter and the signal receiver; and
c. operating the subsea device (150; 250; 350) by means of the control circuit (140; 240; 340).

15. A control system for controlling a subsea slug detector, wherein the control system comprises:

a. a subsea control circuit (340) for operating the subsea slug detector; and
b. a flexible production riser (320) comprising:

- an outer sheath;
- a bore;
- an energy supply line (321) embedded between said outer sheath and said bore and suitable for providing energy to the subsea slug detector; and
- a signal line (322) for transmitting a signal to and from the subsea slug detector,
wherein the energy supply line (321) optionally may be the signal line (322).

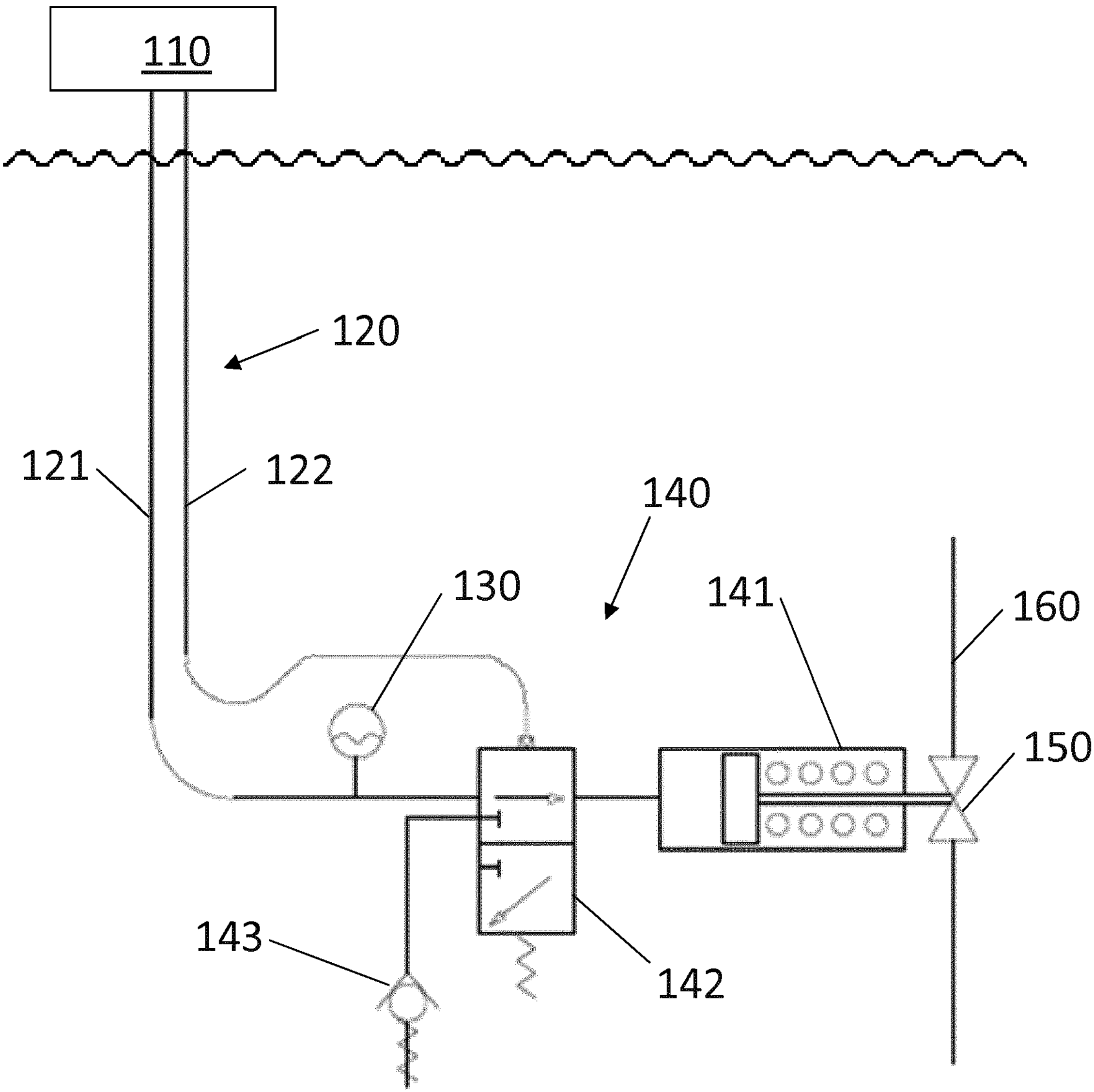

Fig. 1

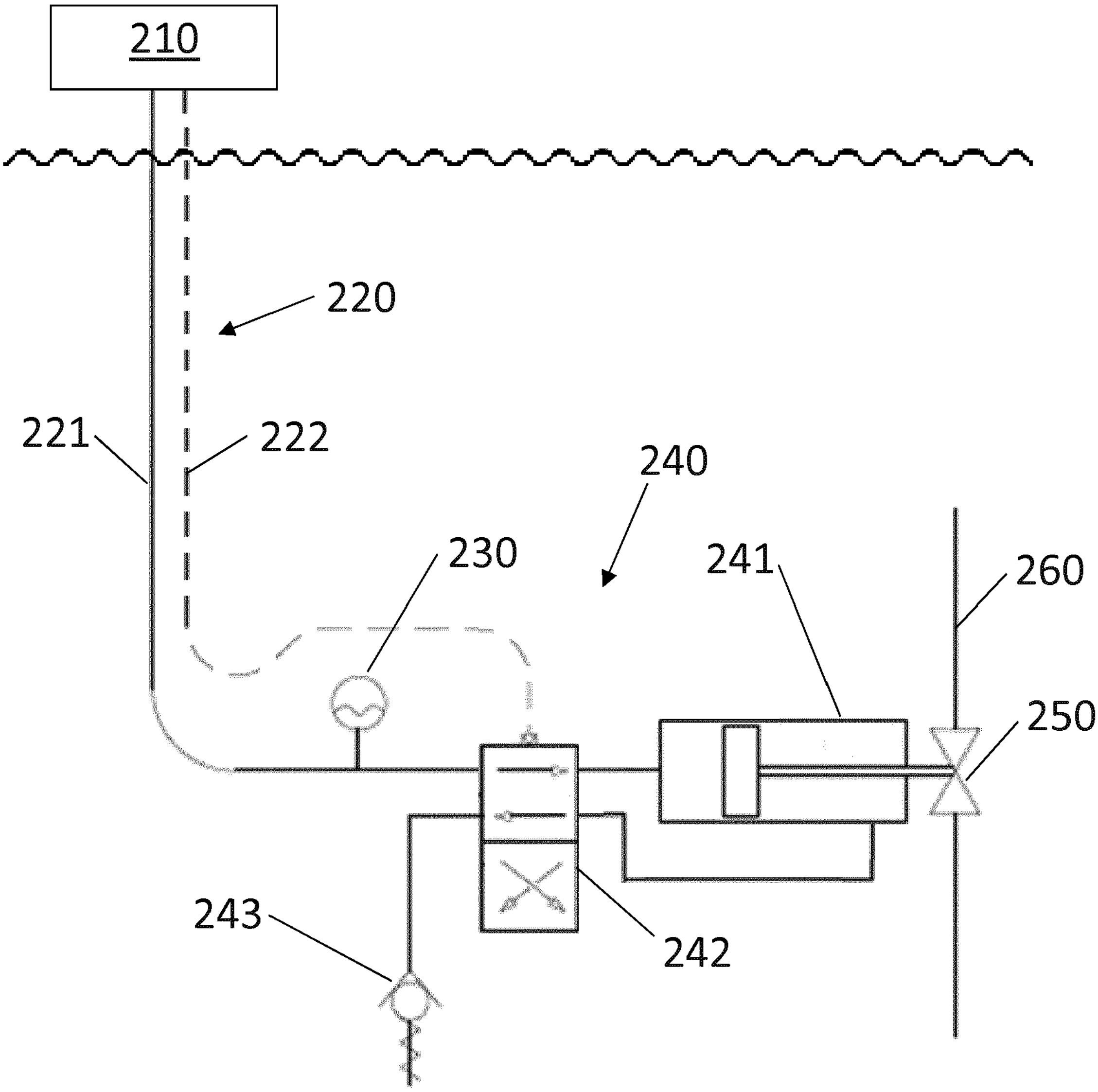

Fig. 2

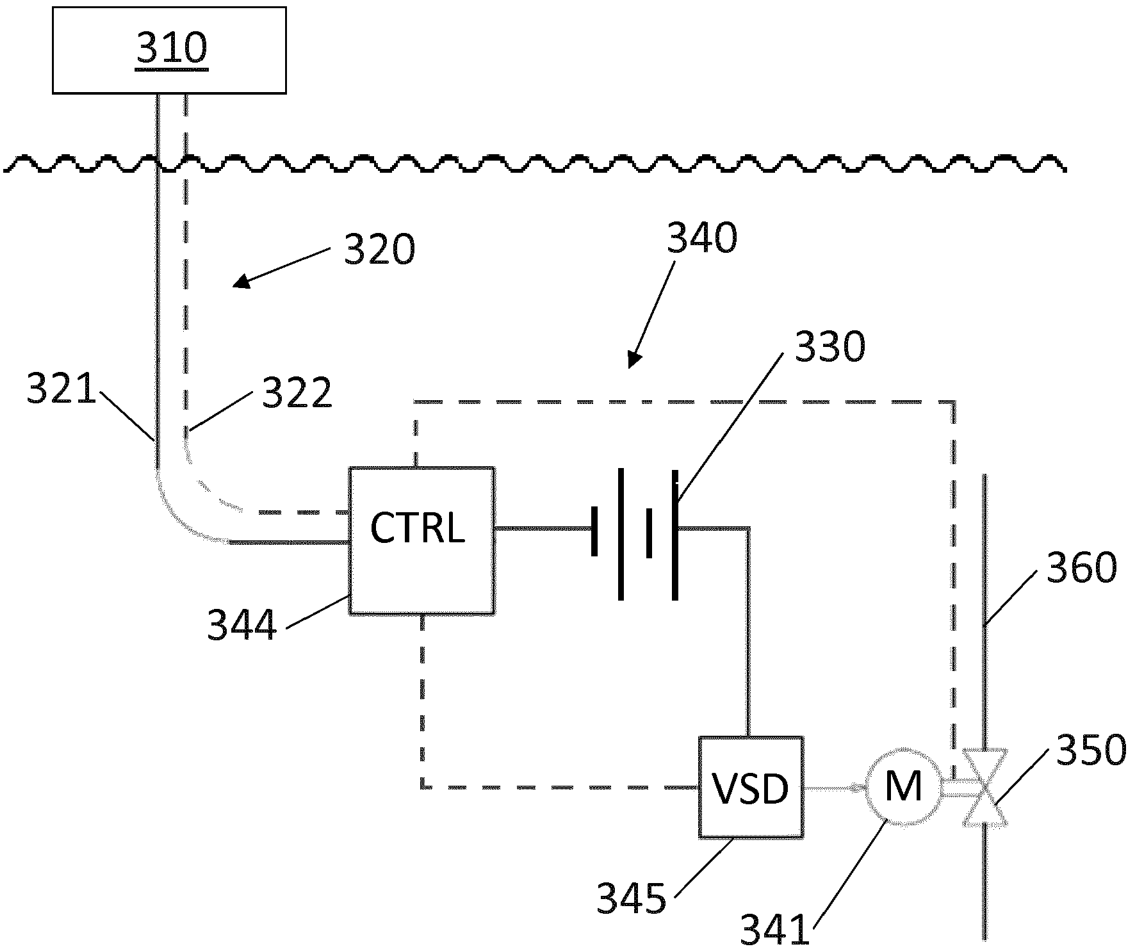

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 19 16 7734

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1

Place of search	Date of completion of the search	Examiner
Munich	11 September 2019	Manolache, Iustin

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X : particularly relevant if taken alone
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