

SUBSEA PUMPING APPARATUSES AND RELATED METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 61/866,483, entitled "INTEGRATED MONITORING, CONTROL, AND ACTUATION FOR BLOWOUT PREVENTER (BOP) HYDRAULIC DEVICES," filed August 15, 2013, the contents of which, to the extent not inconsistent with the present disclosure, are incorporated by reference in their entirety.

BACKGROUND

1. Field of Invention

[0002] The present invention relates generally to subsea pumping, and more specifically, but not by way of limitation, to subsea pumping apparatuses configured to, for example, provide hydraulic fluid to a subsea hydraulically actuated device (e.g., of a blowout preventer).

2. Description of Related Art

[0003] A blowout preventer is a mechanical device, usually installed redundantly in stacks, used to seal, control, and/or monitor oil and gas wells. Typically, a blowout preventer includes a number of components, such as, for example, rams, annulars, accumulators, test valves, kill and/or choke lines and/or valves, riser connectors, hydraulic connectors, and/or the like, many of which may be hydraulically actuated.

[0004] Typically, in a subsea well, such hydraulic actuation is achieved by pumping hydraulic fluid from a surface installation, through one or more hydraulic lines, and to the subsea blowout preventer.

[0005] Examples of subsea pumps are disclosed in U.S. Patent Nos. 8,382,457; 8,500,419; and 8,083,501.

SUMMARY

[0005a] An aspect of the present invention provides a subsea pumping apparatus comprising: one or more subsea pumps, each having an inlet and an outlet; one or more motors, each configured to actuate at least one of the one or more pumps to communicate a hydraulic fluid from the inlet to the outlet; one or more valves, each in fluid communication with the outlet of at least one of the one or more pumps such that, when the subsea pumping

apparatus is coupled to a hydraulically-actuated device and hydraulic fluid flows from the outlet of the pump, the valve is movable between: a first position in which the hydraulic fluid is directed to the hydraulically-actuated device; and a second position in which the hydraulic fluid is directed to at least one of a subsea environment, a reservoir, and the inlet of the pump; and a processor configured to adjust a pressure and/or a flow rate of hydraulic fluid provided to the hydraulically-actuated device by at least one of the one or more pumps by moving at least one of the one or more valves between the first position and the second position.

[0005b] An aspect of the present invention provides a subsea pumping apparatus comprising: one or more subsea pumps, each having an inlet and an outlet; one or more motors, each configured to actuate at least one of the one or more pumps to communicate a hydraulic fluid from the inlet to the outlet; and a desalination system configured to desalinate sea water to produce at least a portion of the hydraulic fluid; where the subsea pumping apparatus is configured to be in fluid communication with a hydraulically actuated device of a blowout preventer.

[0005c] An aspect of the present invention provides a subsea pumping apparatus comprising: one or more subsea pumps, each having an inlet and an outlet; one or more motors, each configured to actuate at least one of the one or more pumps to communicate a hydraulic fluid from the inlet to the outlet; and one or more valves, each in fluid communication with the outlet of at least one of the one or more pumps and configured to selectively route hydraulic fluid from the outlet to at least one of a subsea environment, a reservoir, and the inlet of the pump; where the subsea pumping apparatus is configured to be in fluid communication with a hydraulically actuated device of a blowout preventer.

[0005d] An aspect of the present invention provides a subsea pumping apparatus comprising: one or more subsea pumps, each having an inlet and an outlet; one or more motors, each configured to actuate at least one of the one or more pumps to communicate a hydraulic fluid from the inlet to the outlet; and a fluid reservoir in fluid communication with at least one of the one or more pumps, the fluid reservoir configured to store at least a portion of the hydraulic fluid; where the subsea pumping apparatus is configured to be in fluid communication with a hydraulically actuated device of a blowout preventer.

[0006] Some embodiments of the present subsea pumping apparatuses are configured, through one or more connectors (e.g., hydraulic stabs, interface ports, and/or the like) and/or a frame and/or housing to directly couple to and/or be in direct fluid communication with a hydraulically actuated device of a blowout preventer (e.g., and thus be disposed above a sea floor).

CLAIMS

1. A subsea pumping apparatus comprising:
 - one or more subsea pumps, each having an inlet and an outlet;
 - one or more motors, each configured to actuate at least one of the one or more pumps to communicate a hydraulic fluid from the inlet to the outlet;
 - one or more valves, each in fluid communication with the outlet of at least one of the one or more pumps such that, when the subsea pumping apparatus is coupled to a hydraulically-actuated device and hydraulic fluid flows from the outlet of the pump, the valve is movable between:
 - a first position in which the hydraulic fluid is directed to the hydraulically-actuated device; and
 - a second position in which the hydraulic fluid is directed to at least one of a subsea environment, a reservoir, and the inlet of the pump; and
 - a processor configured to adjust a pressure and/or a flow rate of hydraulic fluid provided to the hydraulically-actuated device by at least one of the one or more pumps by moving at least one of the one or more valves between the first position and the second position.
2. The subsea pumping apparatus of claim 1, comprising a desalination system configured to desalinate sea water to produce at least a portion of the hydraulic fluid.
3. The subsea pumping apparatus of claim 2, where the desalination system comprises:
 - a reverse osmosis membrane; and
 - a pump configured to pass sea water through the membrane to produce the hydraulic fluid.

4. The subsea pumping apparatus of any of claims 1-3, comprising a fluid reservoir in fluid communication with at least one of the one or more pumps, the fluid reservoir configured to store at least a portion of the hydraulic fluid.
5. The subsea pumping apparatus of claim 4, where the fluid reservoir comprises an accumulator.
6. The subsea pumping apparatus of any of claims 4-5, where the fluid reservoir comprises a piston configured to vary an internal volume of the fluid reservoir, the piston having a surface exposed to sea water.
7. The subsea pumping apparatus of any of claims 4-6, where the fluid reservoir comprises a flexible bladder.
8. The subsea pumping apparatus of any of claims 4-7, where the fluid reservoir comprises an ambient pressure reservoir.
9. The subsea pumping apparatus of any of claims 1-8, where at least a portion of the subsea pumping apparatus is configured to be retrievable by a remotely operated underwater vehicle (ROV).
10. The subsea pumping apparatus of any of claims 1-9, comprising one or more ROV stabs configured to allow at least one of electrical or hydraulic ROV control of the subsea pumping apparatus.
11. The subsea pumping apparatus of any of claims 1-10, where at least one of the one or more pumps comprises a piston pump, diaphragm pump, centrifugal pump, vane pump, gear pump, gerotor pump, or screw pump.
12. The subsea pumping apparatus of any of claims 1-11, where at least one of the one or more pumps comprises a variable displacement pump.
13. The subsea pumping apparatus of any of claims 1-12, where at least one of the one or more pumps comprises a fixed displacement pump.
14. The subsea pumping apparatus of any of claims 1-13, where at least one of the one or more pumps comprises a bidirectional pump.

15. The subsea pumping apparatus of any of claims 1-14, where the outlet of at least one of the one or more pumps is in fluid communication with the inlet of at least one other pump.
16. The subsea pumping apparatus of any of claims 1-15, where the outlet of at least one of the one or more pumps is in fluid communication with the outlet of at least one other pump.
17. The subsea pumping apparatus of any of claims 1-16, where the one or more pumps comprises two pumps.
18. The subsea pumping apparatus of any of claims 1-17, comprising a sealed fluid-filled pump chamber, at least one of the one or more pumps disposed within the pump chamber.
19. The subsea pumping apparatus of any of claims 1-18, where the hydraulic fluid comprises at least one of sea water, desalinated water, treated water, and an oil-based fluid.
20. The subsea pumping apparatus of any of claims 1-19, comprising a treatment system configured to supply a dopant to at least a portion of the hydraulic fluid.
21. The subsea pumping apparatus of claim 20, where the treatment system comprises a dopant pump configured to supply the dopant to the hydraulic fluid.
22. The subsea pumping apparatus of claim 20 or 21, where the treatment system comprises a dopant reservoir configured to store at least a portion of the dopant.
23. The subsea pumping apparatus of any of claims 1-22, where at least a portion of the hydraulic fluid is stored above sea.
24. The subsea pumping apparatus of any of claims 1-23, comprising a hydraulic connector in fluid communication with at least one of the one or more pumps and configured to be coupled to at least one of a rigid conduit and a hot line to supply at least a portion of the hydraulic fluid to the subsea pumping apparatus.
25. The subsea pumping apparatus of any of claims 1-24, comprising a fluid rail in fluid communication with the outlet of at least one of the one or more pumps.
26. The subsea pumping apparatus of any of claims 1-25, comprising one or more regulators configured to deliver hydraulic fluid from the subsea pumping apparatus to the hydraulically actuated device at one or more pressures.

27. The subsea pumping apparatus of any of claims 1-26, comprising a filtering system configured to filter the hydraulic fluid.
28. The subsea pumping apparatus of claim 27, where the filtering system comprises a filter.
29. The subsea pumping apparatus of claim 27 or 28, where the filtering system comprises a pump.
30. The subsea pumping apparatus of any of claims 27-29, where the filtering system comprises a bypass valve configured to selectively divert fluid around at least a portion of the filtering system.
31. The subsea pumping apparatus of any of claims 1-30, comprising an ultraviolet (UV) light configured to expose at least a portion of the hydraulic fluid to UV light.
32. The subsea pumping apparatus of any of claims 1-31, where at least one of the one or more motors comprises a synchronous alternating current (AC) motor, an asynchronous AC motor, a brushed direct current (DC) motor, a brushless DC motor, or a permanent magnet DC motor.
33. The subsea pumping apparatus of any of claims 1-32, where at least one of the one or more motors is configured to actuate at least two of the one or more pumps.
34. The subsea pumping apparatus of any of claims 1-33, where at least one of the one or more motors is coupled to at least one of the one or more pumps via a gear box.
35. The subsea pumping apparatus of any of claims 1-34, where at least one of the one or more motors is directly coupled to at least one of the one or more pumps such that neither a shaft seal of the motor nor a shaft seal of the pump is exposed to the subsea environment.
36. The subsea pumping apparatus of any of claims 1-35, comprising a control circuit, the control circuit comprising one or more motor controllers, each motor controller in electrical communication with at least one of the one or more motors and configured to selectively adjust a speed of the motor.

37. The subsea pumping apparatus of claim 36, where at least one of the one or more motor controllers is configured to adjust a speed of a motor by selectively activating and deactivating the motor.

38. The subsea pumping apparatus of claim 36 or 37, where at least one of the one or more motor controllers is configured to selectively adjust a speed of a motor to a speed selected from at least three pre-determined speeds.

39. The subsea pumping apparatus of any of claims 1-38, comprising:
a control circuit, the control circuit comprising one or more valve controllers;
where each valve controller is in electrical communication with at least one of the one or more valves and is configured to adjust an output of the pump by selectively varying the position of the valve between an open and a closed position.

40. The subsea pumping apparatus of claim 1-39, comprising one or more sensors coupled to the subsea pumping apparatus and configured to capture data indicative of at least one of pressure, flow rate, temperature, conductivity, pH, position, velocity, acceleration, current, and voltage.

41. The subsea pumping apparatus of claim 40, comprising circuitry for communicating a signal indicative of the data captured by the one or more sensors.

42. The subsea pumping apparatus of claim 41, comprising a memory coupled to the circuitry.

43. The subsea pumping apparatus of claim 40, comprising a processor configured to control, based at least in part on the data captured by the one or more sensors, actuation of at least one of: at least one of the one or more motors and at least one of the one or more pumps.

44. The subsea pumping apparatus of claim 43, where the processor is configured to:
detect, based at least in part on the data captured by the one or more sensors, an
abnormal operation associated with one or more components including at least
one of: at least one of the one or more pumps, at least one of the one or more
motors, hydraulically actuated device, and blowout preventer;
perform a diagnostic analysis of the one or more components; and
control the one or more components based at least in part on at least one of the
detected abnormal operation and a result of the diagnostic analysis.
45. The subsea pumping apparatus of claim 43 or 44, comprising a memory coupled to
the processor.
46. The subsea pumping apparatus of any of claims 43-45, comprising a battery
configured to provide electrical power to the processor.
47. The subsea pumping apparatus of any of claims 43-46, where the processor is coupled
to the subsea pumping apparatus.
48. The subsea pumping apparatus of any of claims 43-47, where the processor is
configured to electrically communicate with an above sea control interface.
49. The subsea pumping apparatus of any of claims 1-48, comprising one or more
batteries coupled to the subsea pumping apparatus and configured to provide electrical power
to at least one of the one or more motors.
50. The subsea pumping apparatus of claim 49, where the one or more batteries are
configured to provide power to a majority of the one or more motors.
51. The subsea pumping apparatus of claim 49 or 50, comprising an atmospheric pressure
vessel, at least one of the one or more batteries disposed within the pressure vessel.
52. The subsea pumping apparatus of any of claims 49-51, comprising a pressure-
compensated fluid-filled chamber, at least one of the one or more batteries disposed in the
fluid-filled chamber.
53. The subsea pumping apparatus of any of claims 1-52, comprising an electrical
connector in electrical communication with at least one of the one or more motors and

configured to be coupled to an auxiliary cable to provide electrical power to the subsea pumping apparatus.

54. The subsea pumping apparatus of claim 53, where the electrical connector comprises an inductive coupler.

55. The subsea pumping apparatus of any of claims 1-54, where the hydraulically actuated device comprises at least one of a ram, an annular, a connector, and a failsafe valve function.

56. The subsea pumping apparatus of any of claims 1-55, where the subsea pumping apparatus is configured to be directly coupled to the blowout preventer.

57. The subsea pumping apparatus of any of claims 1-56, where the subsea pumping apparatus is configured to be directly coupled to a subsea pumping apparatus of any of claims 1-56.

58. A redundant pressure system comprising:
a first flow source comprising a rigid conduit configured to provide hydraulic fluid to a hydraulically actuated device; and
a second flow source comprising a subsea pumping apparatus of any of claims 1-57 configured to provide hydraulic fluid to the hydraulically actuated device;
where the first and second flow sources are configured to simultaneously supply hydraulic fluid to the hydraulically actuated device.