

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; and one or more hydraulic stabs, each in fluid communication with at least one of the one or more pumps; where the subsea pumping

apparatus is configured to be in direct fluid communication with a hydraulically actuated device of a blowout preventer via the one or more hydraulic stabs.

[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).

of a motor by selectively activating and deactivating the motor. In some embodiments, 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.

[0027] Some embodiments comprise 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 a pump by selectively varying the position of the valve between an open and a closed position.

[0028] Some embodiments comprise 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. Some embodiments comprise circuitry for communicating a signal indicative of the data captured by the one or more sensors. Some embodiments comprise a memory coupled to the circuitry.

[0029] Some embodiments comprise 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. In some embodiments, 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. Some embodiments comprise a memory coupled to the processor. In some embodiments, the processor is configured to electrically communicate with an above sea control interface. Some embodiments comprise a battery configured to provide electrical power to the processor. In some embodiments, the processor is coupled to the subsea pumping apparatus.

[0030] Some embodiments of the present redundant pressure systems comprise a first flow source comprising a rigid conduit configured to provide hydraulic fluid to a hydraulically actuated device and a second flow source comprising one or more of the present subsea pumping apparatuses 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.

[0031] ~~Some embodiments~~ An aspect of the present invention provides a method for actuating a plurality of subsea pumps disposed on a subsea pumping apparatus, the method comprising: actuating at least a first pump via electrical power from an auxiliary cable and actuating at least a second pump via electrical

power from a battery disposed on the subsea pumping apparatus.

~~Some embodiments comprise~~ An aspect of the present invention provides a method for actuating a plurality of subsea pumps disposed on a subsea pumping apparatus, the method comprising: actuating at least a first pump with a first level of power provided by a first auxiliary cable and actuating at least a second pump with a second level of power provided by a second auxiliary cable, where the first level of power is equal to or larger than the second level of power. In some embodiments, at least one pump is in series with at least one other pump. In some embodiments, at least one pump is in parallel with at least one other pump.

[0032] ~~Some embodiments comprise~~ An aspect of the present invention provides a methods for actuating one or more subsea pumps disposed on a subsea pumping apparatus, the method comprising actuating a valve of the subsea pumping apparatus to divert hydraulic fluid from an outlet of at least one of the one or more pumps and routing the diverted hydraulic fluid to at least one of a subsea environment, a reservoir, and an inlet of the at least one of the one or more pumps.

[0033] ~~Some embodiments comprise~~ An aspect of the present invention provides a methods for actuating one or more subsea pumps disposed on a subsea pumping apparatus, the method comprising selectively activating and deactivating at least one motor configured to actuate at least one of the one or more pumps.

[0034] ~~Some embodiments comprise~~ An aspect of the present invention provides a methods for subsea production of hydraulic fluid for actuating a hydraulically actuated device, comprise the method comprising pumping sea water through a subsea membrane to produce the hydraulic fluid. Some embodiments comprise mixing at least a portion of the hydraulic fluid with a dopant.

[0035] ~~Some embodiments comprise~~ An aspect of the present invention provides a methods for actuating a hydraulically actuated device, comprise comprising providing hydraulic fluid to the hydraulically actuated device using one or more pumps disposed on a subsea pumping apparatus, where the one or more pumps are in direct fluid communication with the hydraulically actuated device. Some embodiments comprise varying an actuation speed of the hydraulically actuated device by varying a speed of a motor coupled to at least one of the one or more pumps. In some embodiments, at least one of the one or more pumps is a bi-directional hydraulic pump.

[0036] ~~Some embodiments comprise~~ An aspect of the present invention provides a methods for controlling a pressure within a subsea hydraulic system, the method comprise comprising determining an amount of hydraulic fluid leakage from the subsea hydraulic system and providing, with one or more subsea pumps, an amount of hydraulic fluid to the subsea hydraulic system that substantially matches the amount of hydraulic fluid leakage.

[0037] ~~Some embodiments comprise~~ An aspect of the present invention provides a methods for controlling a plurality of motor-actuated subsea pumps comprise comprising recording a run-time of a first motor over a pre-determined period of time and deactivating the first motor and activating a second motor if the recorded

run-time exceeds a pre-determined threshold. ~~Some embodiments~~ An aspect of the present invention provides a method for controlling a plurality of motor-actuated subsea pumps ~~comprise comprising~~ recording a number of motor activations of a first motor over a first pre-determined period of time and activating a second motor in lieu of the first motor during a second pre-determined period of time if the number of motor activations of the first motor over the first pre-determined period of time exceeds a pre-determined threshold. ~~Some embodiment~~ An aspect of the present invention provides a method for controlling a plurality of motor-actuated subsea pumps ~~comprise comprising~~ recording a number of motor activations of a motor over a first pre-determined period of time and not deactivating the motor, if the motor is activated, for a second pre-determined period of time if the number of motor activations of the motor over the first pre-determined period of time exceeds a pre-determined threshold.

[0038] As used in this disclosure, the term “blowout preventer” includes, but is not limited to, a single blowout preventer, as well as a blowout preventer assembly that may include more than one blowout preventer (e.g., a blowout preventer stack).

[0039] Hydraulic fluids of and/or suitable for use in the present pumping apparatuses can comprise any suitable fluid, such as, for example, sea water, desalinated water, treated water, an oil-based fluid, mixtures thereof, synthetic fluids, plant-based fluids, and/or the like.

[0040] The term “coupled” is defined as connected, although not necessarily directly, and not necessarily mechanically. The terms “a” and “an” are defined as one or more unless this disclosure explicitly requires otherwise. The term “substantially” is defined as largely but not necessarily wholly what is specified (and includes what is specified; e.g., substantially 90 degrees includes 90 degrees and substantially parallel includes parallel), as understood by a person of ordinary skill in the art. In any disclosed embodiment, the terms “substantially” and “approximately” may be substituted with “within [a percentage] of” what is specified, where the percentage includes .1, 1, 5, and 10%.

[0041] Further, a device or system that is configured in a certain way is configured in at least that way, but it can also be configured in other ways than those specifically described.

[0042] The terms “comprise” (and any form of comprise, such as “comprises” and “comprising”), “have” (and any form of have, such as “has” and “having”), “include” (and any form of include, such as “includes” and “including”), and “contain” (and any form of contain, such as “contains” and “containing”) are open-ended linking verbs. As a result, an apparatus that “comprises,” “has,” “includes,” or “contains” one or more elements possesses those one or more elements, but is not limited to possessing only those elements. Likewise, a method that “comprises,” “has,” “includes,” or “contains” one or more steps possesses those one or more steps, but is not limited to possessing only those one or more steps.