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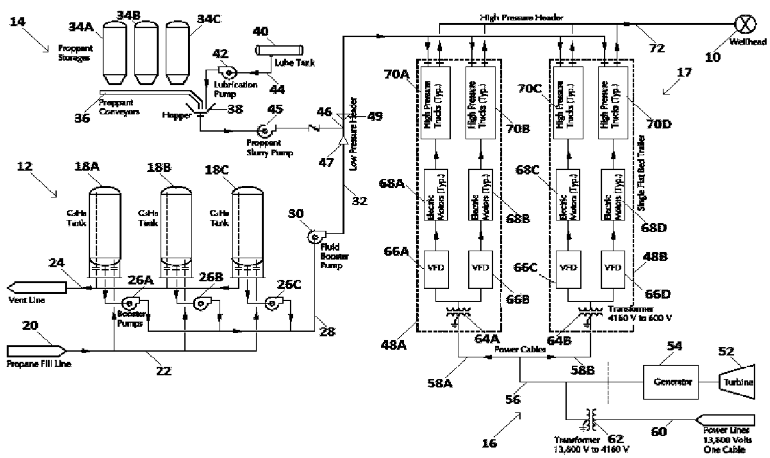

FIG 1

(57) Abstract: The disclosure contained herein describes systems, units, and methods usable to stimulate a formation including a pump usable to pressurize fluid, an electric-powered driver in communication with and actuating the pump, and an electrical power source in communication with and powering the electric-powered driver. The electrical power source can include on- site generators and/or grid power sources, and transformers can be used to alter the voltage received to a voltage suitable for powering the electric-powered driver. Air moving devices associated with the electric-powered driver can be used to provide air proximate to the pump to disperse gasses. In combination with fluid supply and/or proppant addition subsystems, the pump can be used to fracture a formation.

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FRACTURING SYSTEMS AND METHODS FOR A WELLBORE

CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This applications claims priority to United States Provisional Application for patent, having the Application Serial Number 61/889,187, filed October 10, 2013.

[002] This applications further claims priority to United States Non-Provisional Application for patent, having the Application Serial Number 14/199461, filed March 3, 2013; and United States Provisional Application for patent, having the Application Serial Number 61/915093, filed December 12, 2013

[003] All the above applications are hereby incorporated by reference in their entirety.

FIELD OF THE INVENTION

[004] The present disclosure relates generally, to systems, methods, devices, and compositions usable within a wellbore, and more specifically, to systems and methods for fracturing a formation to stimulate production (e.g., of hydrocarbons) therefrom.

BACKGROUND OF THE INVENTION

[005] To stimulate and/or increase the production of hydrocarbons from a well, a process known as fracturing (colloquially referred to as “fracing”) is performed. In brief summary, a pressurized fluid – often water – is pumped into a producing region of a formation at a pressure sufficient to create fractures in the formation, thereby enabling hydrocarbons to flow from the formation with less impedance. Solid matter, such as sand, ceramic beads, and/or similar particulate-type materials, can be mixed with the fracturing fluid, this material generally remaining within the fractures after the fractures are formed. The solid material, known as proppant, serves to prevent the fractures from closing and/or significantly reducing in size following the fracturing operation, e.g., by "propping" the fractures in an open position. Some types of proppant can also facilitate the formation of fractures when pumped into the formation under pressure. While the presence of proppant in the fractures can hinder the permeability of the formation, e.g., by impeding the flow of hydrocarbons toward the wellbore, the increased flow created by the propped fractures normally outweighs any impedance caused by the proppant. The materials being transported into a formation for the purposes of fracturing may be referred to as "fracturing material." The fracturing material may comprise any material that is being transported into a formation for fracturing purposes, and may include fluids, gasses, solids, or combinations thereof.

[006] Fracturing using aqueous fluids is often undesirable due to the negative effects of water on the formation. For example, clays and other formation components can swell when exposed to water, while salts and other formation components may dissolve, such that exposure to a significant quantity of water can destabilize a formation. Use of water and other aqueous fluids also generates issues regarding disposal. Specifically, aqueous fracturing fluid recovered from a well (e.g., subsequent to a fracturing operation) contains various wellbore fluids and other chemicals (e.g., additives to facilitate fracturing using the fluid), and as such, the recovered fracturing fluid must be collected and stored at the surface and disposed of in an environmentally acceptable manner, as required by numerous regulations. Such a process can add considerable time and expense to a fracturing operation.

[007] Non-aqueous fracturing fluids have been used as an alternative, one such successful class including hydrocarbon-based fluids (e.g., crude/refined oils, methanol, diesel, condensate, liquid petroleum glass (LPG) and/or other aliphatic or aromatic compounds). Hydrocarbon-based fracturing fluids are inherently compatible with most reservoir formations, being generally non-damaging to formations while creating acceptable fracture geometry. However, due to the flammability of hydrocarbon-based fluids, enhanced safety preparations and equipment are necessary when using such fluids for wellbore operations. Additionally, many hydrocarbon-based fluids are volatile and/or otherwise unsuitable for use at wellbore temperatures and pressures, while lacking the density sufficient to carry many types of proppant. As such, it is common practice to use chemical additives (e.g., gelling agents, viscosifiers, etc.) to alter the characteristics of the fluids. An example a system describing use of liquid petroleum gas is described in U.S. Patent 8,408,289, which is incorporated by reference herein in its entirety. Use of chemical additives generates waste and disposal issues similar to those encountered when performing fracturing operations using aqueous fluids.

[008] Independent of the type of fracturing fluid and proppant used, a fracturing operation typically requires use of one or more high pressure pumps to pressurize the fracturing fluid that is pumped into a wellbore. Conventionally, such equipment is driven/powered using diesel engines, which can be responsible for significant quantities of noise, pollution, and expense at a worksite. Electric drive systems have been contemplated as an alternative to diesel engines; however, such systems require numerous pieces of equipment, extensive cabling and/or similar conduits, and typically utilize on-site power generation, such as a natural gas turbine. Use of turbine prime movers and similar equipment may be unsuitable when utilizing fracturing fluids that include flammable components. An exemplary electrically powered system for use in fracturing underground formations is described in published United States Patent Application 2012/0255734, which is incorporated by reference herein in its entirety.

[009] A need exists for systems and methods for fracturing and/or stimulating a subterranean formation that can overcome issues of formation damage/compatibility, flammability, proppant delivery, and/or power supply.

BRIEF SUMMARY OF THE INVENTION

[0010] Embodiments usable within the scope of the present disclosure include systems usable for stimulating a formation (e.g., by forming fractures therein), such as through the provision of pressurized fluid to the formation through a wellbore. A fluid supply system, adapted to provide a fluid (e.g., a fracturing fluid, such as propane, other alkanes, halogenated hydrocarbons, other hydrocarbons, or any other fracturing fluid, such as water) can be provided in fluid communication with the formation. A power subsystem that includes one or more pumps (e.g., high pressure pumps, usable for fracturing operations) in communication with the fluid can be used to pressurize the fluid to a pressure sufficient to stimulate the formation. In an embodiment, a proppant addition system can be used to provide solid material (e.g., proppant, such as sand, ceramic, beads, glass bubbles, crystalline materials, or any other solid and/or particulate matter usable to maintain fractures in a formation) into the fluid.

[0011] In addition to the one or more pumps, the power subsystem can include an electric-powered driver (e.g., an electric motor) in communication with and actuating the pump(s), and an electrical power source (e.g., a turbine-powered generator, a grid power source, and/or another source of AC or DC power), in communication with and powering the electric-powered driver. Alternatively or additionally, a generator can be powered using reciprocating engines (e.g., diesel engines) without departing from the scope of the present disclosure. A single pump can be actuated using a single electric-powered driver or multiple electric-powered drivers, and multiple pumps can be actuated using a single electric-powered driver or multiple electric-powered drivers. Similarly, a single power source can power one or multiple electric-powered drivers, or one or multiple electric-powered drivers can be powered by multiple power sources. In an embodiment, the power subsystem can be adapted for simultaneous or selective/alternative use of an on-site power source, such as a generator powered by a natural gas turbine, or a grid power source (e.g., power lines or similar conduits associated with a remote power source).

[0012] One or more transformers can be used to alter voltage from the power source to a voltage suitable for powering the electric-powered drivers. One or more variable frequency drives ("VFD(s)") can be provided in communication with the transformer(s) and respective electric-powered drivers.

[0013] In an embodiment, at least one VFD, electric-powered driver, and pump can be provided on a mobile vehicle to facilitate modular positioning, e.g., at a worksite. One or more transformers can also be provided, on or off of the mobile vehicle. An electrical power source can be engaged with a transformer (and subsequently, to other associated components) via a single electric conduit, eliminating much of the cabling/conduits present at conventional worksites.

[0014] In an embodiment, an air-moving device (e.g., a blower) associated with the electric-powered driver (typically used to cool the electric-powered driver), can be used to flow air proximate to a pump, e.g., for dispersing volatile gases. For example, when using propane as a fracturing fluid, the accumulation of propane proximate to the pump could create a flammable condition (e.g., at a propane concentration of approximately 2.2% to 9.5% in air), while the continuous movement of air proximate to the pump would prevent accumulation of flammable components at a concentration sufficient for ignition. An enclosed conduit extending between the electric-powered driver and the pump can be used to facilitate the flow of air. Alternatively or additionally, the electric-powered driver and the pump could occupy a single housing. In one embodiment, one or more protrusions (e.g., fins, blades, or similar projections) extending from the drive shaft extending between the electric-powered driver and the pump can be contacted by air from the air-moving device, such that the flow of air imparts motive force to the drive shaft. The rotation of such protrusions, itself (e.g., when the drive shaft is rotated to actuate the pump), can serve to circulate air proximate to the pump, in addition to or in lieu of an air-moving device associated with the electric-powered driver.

[0015] Embodiments of the system usable within the scope of this disclosure may provide for VFD(s) having an active front end. The active front end that may be used with the VFD(s) actively switches insulated-gate bipolar transistors (IGBT's) at a frequency of approximately 3,500Hz and inductor-capacitor-inductor passive filters (LCLs). Actively filtering the signals inputted into the VFD the enables active signal modulation which reduces the possibility of, and may be used to actively prevent, the system developing harmonics that could adversely affect the transport of the fracturing materials. Such an active front end provides for superior line canceling harmonics when using electricity from the power grid as compared to conventional diode bridge rectifies, or other passive filtering techniques.

[0016] Furthermore, embodiments of the system may comprise a logic system for controlling multiple pumps used in the same fracturing operation at the same time. The logic system may comprise one or more sensors that actively monitor a multitude of different parameters of the pumping system. The logic system may further comprise an active feedback loop that uses the data collected by the sensor(s) in order to responsively modulate the characteristics of the pumping action of one or more pumps in order to optimize the flow of fracturing materials into the formation and/or to prevent potentially hazardous conditions from arising due to the interactions between multiple pump systems.

[0017] The electrical components of the system described herein may be operated at any of a multitude of different voltages; however, without disclaiming any functional voltage ranges, for the purposes of the description of embodiments in the present disclosure it will be assumed that the voltage of operation is approximately 4160 volts or “Medium Voltage”.

[0018] The use of Medium Voltage is specifically described herein because it affords a number of potential benefits to the system. Such advantages include the elimination of the need for a front end transformer for converting incoming electricity from a power source to a voltage that is useable by a VFD. The elimination of the front end transformers reduces the amount of equipment required for use of the system, which in turn reduces the cost and logistical requirements, (e.g. the cost of the front end transformer(s) themselves, the cost and planning of transportation of the equipment, weight of equipment on site, etc.) of setting up and running the system.

[0019] Furthermore the use of Medium Voltage allows for fewer and/or smaller electrical cables running between the electrical components of the system than would be required in a lower voltage configuration. The reduction of cables reduces both the cost of setting up the system and the clutteredness of the work site.

[0020] Included in the scope of the present disclosure is an electrical power system for providing fracturing materials to a formation at a pressure sufficient to stimulate the formation. The electrical power system comprises at least one pump, at least one electric-powered driver, and at least one VFD. In an embodiment of the system the VFD receives electricity from an electrical power source, the VFD then converts that electricity into an electrical signal that is then transmitted to the electric-powered driver. The electric-powered driver converts the electrical signal provided by the VFD into mechanical energy that is used to actuate the pump. The actuation of the pump by the mechanical energy produced by the electric-powered driver causes the pump to pressurize a volume of fracturing material. The pressurized fracturing material may be transported into a formation for the purposes of stimulating the formation.

[0021] Embodiments of the electrical power system may be configured so that a single VFD may provide the electrical signal to a plurality of electrical motors, each of which power an associated pump. This configuration wherein a single VFD powers multiple motor/pump combinations may provide benefits to fracturing systems that require fracturing material to be transported to a formation at a high flow rate but at a low pressure.

[0022] Alternate embodiments of the electrical power system may be configured so that a single VFD may provide the electrical signal to a single motor/pump combination. This configuration may provide for benefits in situations when a fracturing system requires fracturing material to be transported to a formation at a high pressure.

[0023] Embodiments of the electrical power system may be configured such that the VFD is positioned proximate to the motor/pump combination(s). This configuration may allow for reduced infrastructure requirements at the operation site, and may enable the entire electrical power system to be configured so as to be supported by, and transportable on, a mobile platform.

[0024] Alternative embodiments of the electrical power system may be configured such that the VFD is positioned in a location remote from the motor/pump combination(s). This configuration may assist in preventing dangers on the site by physically removing potential ignition sources (the VFD) from proximity with the components of the system that interact with the fracturing materials. This may be of particular importance when the fracturing materials being pressurized comprise volatile materials.

[0025] Embodiment of the electrical power system may comprise an electric-powered driver(s) that are designed to be fire and/or explosion resistant.

[0026] Embodiments of the electrical power system may further comprise a proppant addition subsystem configured to add proppant to the fracturing materials being pressurized.

[0027] The electrical power system may further comprise an agitator configured to enable viscous fracturing materials to be transported to the formation. Such an agitator may use vibration to enable the transportation of the viscous fracturing material.

[0028] Embodiments of the electrical power system may further comprise a transformer for converting the electricity being received from a first voltage to a second voltage prior to the electricity being inputted into the VFD.

[0029] Additionally included in the scope of the present disclosure is a method of electrically powering a system for providing a fracturing material to a formation at a pressure sufficient to stimulate the formation. An embodiment of the method comprises first receiving electricity from a power source. The electricity is inputted into a VFD which converts the electricity into a electrical signal. The electrical signal is then transferred from the VFD to an electrical motor. The electrical motor converts the electrical signal provided from the VFD into mechanical energy. The mechanical energy from the electrical motor is communicated to a pump which uses the mechanical energy from the electrical motor to pressurize a volume of fracturing material.

[0030] Embodiments of the method may further comprise the step of converting the electricity being received from a first voltage to a second voltage prior to the electricity being inputted into the VFD. A transformer may be used to convert the electricity from the first voltage to the second voltage. This step may be required when the voltage being provided by the power source is outside of the range of voltages usable by the VFD.

[0031] Embodiments of the method may provide for transmitting a portion of the electrical signal provided by the VFD to a plurality of electric-powered drivers. The portion of the electrical signal may be provided to the plurality of eclectic motors in series or in parallel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The novel features believed characteristic of the disclosed subject matter will be set forth in any claims that are filed later. The disclosed subject matter itself, however, as well as a preferred mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

[0033] In the detailed description of various embodiments usable within the scope of the present disclosure, presented below, reference is made to the accompanying drawings, in which:

[0034] Figure 1 depicts a diagram of an embodiment of a system usable within the scope of the present disclosure.

[0035] Figure 2A depicts a diagrammatic side view of an embodiment of a motor engaged with a pump, usable within the scope of the present disclosure.

[0036] Figure 2B depicts a diagrammatic side view of an embodiment of a motor engaged with a pump, usable within the scope of the present disclosure.

[0037] Figure 2C depicts a diagrammatic side view of an embodiment of a motor engaged with a pump, usable within the scope of the present disclosure.

[0038] Figure 3 depicts a diagrammatic side view of an embodiment of a motor engaged with a pump, usable within the scope of the present disclosure.

[0039] Figure 4 depicts a diagrammatic side view of an embodiment of a motor engaged with a pump, usable within the scope of the present disclosure.

[0040] Figure 5 depicts a diagrammatic side view of an embodiment of a VFD usable within the scope of the present disclosure.

[0041] Figure 6 depicts a diagrammatic view of an embodiment of an electrical pumping system for supplying fracturing materials to a formation, usable within the scope of the present disclosure.

[0042] Figure 7 depicts a diagrammatic view of an embodiment of an electrical pumping system for supplying fracturing materials to a formation, usable within the scope of the present disclosure.

[0043] Figure 8 depicts a diagrammatic view of an embodiment of an electrical pumping system for supplying fracturing materials to a formation, usable within the scope of the present disclosure.

[0044] One or more embodiments are described below with reference to the listed Figures.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0045] Reference now should be made to the drawings, in which the same reference numbers are used throughout the different figures to designate the same components.

[0046] Before describing selected embodiments of the present invention in detail, it is to be understood that the present invention is not limited to the particular embodiments described herein. The disclosure and description herein is illustrative and explanatory of one or more presently preferred embodiments of the invention and variations thereof, and it will be appreciated by those skilled in the art that various changes in the design, organization, order of operation, means of operation, equipment structures and location, methodology, and use of mechanical equivalents may be made without departing from the spirit of the invention.

[0047] As well, it should be understood the drawings are intended illustrate and plainly disclose presently preferred embodiments of the invention to one of skill in the art, but are not intended to be manufacturing level drawings or renditions of final products and may include simplified conceptual views as desired for easier and quicker understanding or explanation of the invention. As well, the relative size and arrangement of the components may differ from that shown and still operate within the spirit of the invention as described throughout the present application.

[0048] Moreover, it will be understood that various directions such as “upper”, “lower”, “bottom”, “top”, “left”, “right”, and so forth are made only with respect to explanation in conjunction with the drawings, and that the components may be oriented differently, for instance, during transportation and manufacturing as well as operation. Because many varying and different embodiments may be made within the scope of the inventive concept(s) herein taught, and because many modifications may be made in the embodiments described herein, it is to be understood that the details herein are to be interpreted as illustrative and non-limiting.

[0049] Figure 1 depicts an embodiment of a system usable to inject a fluid under pressure into a well (10). For example, the depicted system can be used to stimulate production (e.g., of hydrocarbons) by forming fractures in the wellbore formation through the provision of a pressurized fracturing fluid into the well (10), mixed with proppant (e.g., solid particulate matter) to maintain and/or support the fractures while permitting the flow of hydrocarbons or other fluids from the formation into the wellbore and toward the surface. Conceptually, Figure 1 subdivides the depicted system into a fluid addition subsystem (12) for providing fracturing fluid to the well (10), a proppant addition subsystem (14) for providing proppant into the fracturing fluid, a power subsystem (16) for providing power to one or more components of the system, and a pumping subsystem (17) for pressurizing fluid for injection into the well (10). It should be understood that the number, type, and arrangement of components shown in Figure 1 is only one exemplary embodiment, and that the depicted illustration is diagrammatic, intended to conceptually depict one embodiment of the present system. As such, it should be noted that any number, type, and arrangement of identical or similar components could be used without departing from the scope of the present disclosure.

[0050] The depicted fluid addition subsystem (12) includes a plurality of tanks (18A, 18B, 18C) and/or other types of vessels usable to contain one or more fluid media usable as a fracturing fluid (e.g., to carry proppant to the well (10) and/or to form fractures in the underlying formation when pressurized). Specifically, the depicted embodiment includes tanks (18A, 18B, 18C) usable to contain liquid propane, or other low weight alkanes (e.g., having from one to six carbon atoms); however, it should be understood that while various embodiments of the present disclosure can include use of propane and/or other alkanes as a fracturing fluid, the depicted system, including the proppant addition subsystem (14) and power subsystem (16), can be used with any type of fracturing fluid (e.g., water).

[0051] While gelled liquid petroleum gas has been used in fracturing fluids to minimize damage to formations, driven by pressure applied using inert gas (e.g., nitrogen), as described in U.S. Patent 8,408,289, which is incorporated by reference herein, embodiments usable within the scope of the present disclosure can include use of liquid propane and/or other alkanes, without the addition of gellants or other chemical additives. Additionally, to reduce or eliminate the flammability of the hydrocarbon-based fracturing fluid, in an embodiment, a halogenated hydrocarbon can be present. For example, 1,1,1,2,3,3,3-Heptafluoropropane, or a similar halogenated hydrocarbon compound composed of an aliphatic or aliphatic derivative (e.g., ethers and/or olefins) with one or more halogen elements (e.g., fluorine, bromine, etc.) could be present in the fracturing fluid, such that the resulting fluid is fire retardant or non-flammable. A portion of the fracturing fluid could include a halogenated compound while still providing the fracturing fluid with fire retardant and/or non-flammable properties, though any quantity of halogenated compounds could be used without departing from the scope of the present disclosure. Additionally, it should be understood that heptaafluoropropane is referenced as an individual exemplary embodiment; hydrofluoroalkenens, hydrofluoroethers, and other types of halogenated compounds can also be used without departing from the scope of the present disclosure. Of note, use of halongenated hydrocarbons can provide additional beneficial properties beyond non-flammability, due in part to the higher fluid density and lower surface tension and viscosity of the halogenated compounds compared to non-halogenated hydrocarbons

[0052] Figure 1 depicts the tanks (18A, 18B, 18C) as generally cylindrical vessels having a vertical orientation. Use of vertically-oriented tanks to contain propane and/or other alkanes (and/or halogenated hydrocarbons) can enable gravity and/or vapor pressure above the contents of the tanks to aid in driving the contents toward the well (10), thus requiring lower energy and/or lower power pumping equipment, while also enabling the tanks to include a smaller quantity of unused volume (e.g., “tank bottoms”) when compared to a horizontally-oriented tank. Vertical tanks also provide a smaller footprint than horizontal tanks and other alternatives. However, it should be understood that any type of vessel usable to contain fracturing fluid can be used without departing from the scope of the present disclosure. In an embodiment, the tanks (18A, 18B, 18C) can include multiple outlets to facilitate flowing of fluid therefrom at a rate sufficient to perform fracturing or other operations. In a further embodiment, the tanks (18A, 18B, 18C) can be portable/transportable (e.g. skid-mounted or otherwise structured to facilitate transportability) in a generally vertical orientation. In other embodiments, use of on-site vessels containing fracturing fluid could be omitted, and pipelines or similar conduits from a remote source could be used to continuously or intermittently supply fracturing fluid to the well (10).

[0053] The tanks (18A, 18B, 18C) are shown in communication with a fluid source (20) for supplying propane and/or other alkanes or hydrocarbons thereto via a fill line (22). A vent line (24) is also usable, e.g., to relieve pressure from the tanks (18A, 18B, 18C) and/or otherwise facilitate flow thereto and therefrom. Each tank (18A, 18B, 18C) is shown in communication with an associated pump (26A, 26B, 26C) (e.g., a booster pump), usable to draw fracturing fluid therefrom and flow the fluid toward the well (10) via a conduit (28). A secondary fluid booster pump (30) is shown for further driving the fluid toward the well (10), through a low pressure region (32) of the conduit. While Figure 1 depicts each tank (18A, 18B, 18C) having a respective associated pump (26A, 26B, 26C) associated therewith, and a secondary booster pump (30) to further drive the fluid, it should be understood that in various embodiments, a secondary pump may be omitted, a single pump could be used to draw fluid from multiple tanks, multiple pumps could be used to draw fluid from a single tank, or use of pumps could be omitted. In an embodiment, gravity, vapor pressure, and/or pressure applied to the tanks (18A, 18B, 18C) and/or the contents thereof using external sources could be used to drive fracturing fluid toward the well (10) in lieu of pumps.

[0054] The depicted proppant addition subsystem (14) includes a plurality of proppant storage vessels (34A, 34B, 34C) (e.g., silos or another type of tank and/or container), positioned in association with a conveyor (36), which can include one or more conveyor belts, chutes, slides, pipes, or other types of conduits and/or means of conveyance usable to transport proppant from the vessels (34A, 34B, 34C) toward a hopper (38) or similar type of container. Use of vertically oriented proppant storage vessels, such as silos, can enable gravity and/or the weight of the proppant to drive proppant from the containers toward the conveyor (36) and/or toward the well (10), while also reducing the footprint presented by the containers. One exemplary proppant storage container could include a Model 424 Sand Silo, produced by Loadcraft Industries, LTD of Brady, Texas, which can include an associated transportation trailer. Proppant within the vessels (34A, 34B, 34C) can include any manner of small and/or particulate solid matter usable to retain and/or support fractures in a formation, such as sand, glass or clay beads, gravel, or other similar types of material and or particulate matter, such as crystalline material (e.g., zircon) and/or hollow glass particles (e.g., glass bubbles/microspheres, such as those made by 3M of St. Paul, Minnesota), among other possible alternatives.

[0055] While Figure 1 depicts three proppant storage vessels (34A, 34B, 34C) in association with a conveyor (36) for transporting the proppant to a hopper (38) or other type of second container, it should be understood that in various embodiments, a single hopper or container could be used, while omitting separate storage containers and a conveyor, or use of a hopper or other type of secondary container could be omitted while proppant is conveyed toward the well (10) directly from storage containers. Generally, the hopper (38) serves as a location where a lubricating fluid from a lubrication source (40) (e.g., a tank) can be provided to dispensed proppant, via a conduit (44) and lubrication pump (42). Usable lubricating fluids can include fracturing fluid identical or similar to that stored in the tanks (18A, 18B, 18C) of the fluid addition subsystem (12), mineral oil, or any other suitable lubricant that is generally non-damaging to system components and compatible with the fracturing fluid in the tanks (18A, 18B, 18C), and the formation and reservoir fluids in the well (10). A proppant pump (45) is usable to drive the proppant and lubricating fluid toward the well (10) and/or to slurry the proppant with the lubricating fluid. The proppant is mixed with the flowstream of fracturing fluid from the fracturing fluid addition subsystem (12) at an addition point (46) within the low pressure region (32) of the conduit, such that the flow of the proppant and fracturing fluid can mix and/or slurry the proppant and fluid (e.g., due to turbulent flow and/or other factors) to achieve a desired proppant concentration. Generation of a slurry of proppant and fracturing fluid having a generally constant proppant concentration enables the amount of proppant added at the addition point (46) to be controlled solely by modifying the rate of addition of the proppant slurry.

[0056] It should be understood that the depicted proppant addition subsystem (14) is only one exemplary embodiment by which proppant can be added to a stream of fracturing fluid. In an embodiment, a venturi nozzle (47) can be positioned in communication with the flowstream of fracturing fluid, e.g., at or near the addition point (46) (e.g., upstream thereof), thereby increasing the velocity and reducing the pressure of fluid at the downstream end of the nozzle (47), such that the flow of lower-pressure fracturing fluid across and/or proximate to the addition point (46) can draw proppant through into the flowstream. A diffuser (49) can be provided downstream from the nozzle (47). An elastomeric (e.g., self-adjusting) nozzle can be used to facilitate a constant pressure drop across the nozzle, thereby facilitating control of the rate/concentration of proppant. Use of a venturi nozzle can further facilitate mixing and/or slurrying of the proppant and fracturing fluid.

[0057] As fracturing fluid and proppant in the low pressure region (32) flows toward the well (10) it is pressurized by one or more high pressure fracturing pumps (70A, 70B, 70C, 70D), defining a high pressure region (72) of the conduit, such that the fluid provided into the well (10) is at a pressure sufficient to generate fractures in the formation. The depicted power subsystem (16) is usable to provide power to the high pressure pumps (70A, 70B, 70C, 70D), and/or to other system components (such as the pumps (26A, 26B, 26C, 30, 42, 45) usable to flow fracturing fluid, proppant, and lubricating fluid, the proppant conveyor (36), one or more valves associated with system components, and/or other similar elements).

[0058] Figure 1 illustrates two methods by which the high pressure pumps (70A, 70B, 70C, 70D) and associated components can be powered; however, it should be understood that while the depicted power subsystem (16) includes the simultaneous and/or selective use of two sources of power, in other embodiments, a single source of power could be used. Additionally, while the depicted power subsystem (16) is used to power the high pressure pumps (70A, 70B, 70C, 70D), it should be understood that the power subsystem (16) can be used to power any portion of the depicted system (e.g., the booster pumps associated with the fluid subsystem, the lubrication and slurry pumps associated with the proppant subsystem, proppant conveyors, various associated valves, as well as other fluid systems (not shown) associated with the well (10)). Specifically, the power subsystem (16) is shown having a turbine (52) (e.g., a natural gas turbine or similar type of device usable to produce mechanical output from other forms of energy) coupled with a generator (54), to produce electricity that can be conducted via a cable (56) or similar conduit to other components of the power subsystem (16). Alternatively or additionally, power can be obtained from an external source (e.g., a municipal power grid, power lines, etc.) (60). While typical electrical power is provided having a voltage of 4,160, in an embodiment, high voltage lines could be used to convey electricity to the system. For example, Figure 1 depicts power lines (60) capable of conveying high voltage, e.g., 13,800 volts or more, to a transformer (62), usable to step down the voltage in the conduit (56) to a typical voltage of 4,160 volts or another usable voltage. Power produced using the generator (54) can be provided at a usable voltage without requiring a transformer; however, a transformer could be used in association with the generator (54) without departing from the scope of the present disclosure.

[0059] While any number and type of high pressure pumps can be used, Figure 1 depicts four high pressure pumps (70A, 70B, 70C, 70D) usable to pressurize the fracturing fluid. The first and second high pressure pumps (70A, 70B) are shown positioned on a first transport vehicle (48A), which can include, by way of example, a flatbed trailer, a truck, a skid, or any other transportable platform or framework. Similarly, the third and fourth high pressure pumps (70C, 70D) are shown positioned on a second transport vehicle (48B).

[0060] Each transport vehicle (48A, 48B) is shown having a transformer (64A, 64B) positioned thereon. Use of a transformer on the vehicle, itself, enables a single respective power cable (58A, 58B) to be extended from the power source to the vehicle (48A, 48B). Conversely, use of a transformer remote from other system components would require numerous cables and/or other conduits extending from the transformer to other system components. As such, positioning of the transformers (64A, 64B) proximate to the high pressure pumps (70A, 70B, 70C, 70D) and other associated components minimizes the distance across which large numbers of cables/conduits must extend. While usable voltages can vary without departing from the scope of the present disclosure, in an embodiment, the transformers (64A, 64B) can be adapted to reduce voltage in the cables (58A, 58B) from 4,160 volts to 600 volts, for use by components associated with the high pressure pumps (70A, 70B, 70C, 70D). Specifically, Figure 1 depicts two VFDs (66A, 66B) in electrical communication with the first transformer (64A), and two VFDs (66C, 66D) in electrical communication with the second transformer (64B). The VFDs (66A, 66B, 66C, 66D) each, in turn, actuate a respective associated electrical motor (68A, 68B, 68C, 68D). Each electrical motor (68A, 68B, 68C, 68D) in turn powers a respective high pressure pump (70A, 70B, 70C, 70D). In an embodiment, the electrical motors can include explosion-proof motors, such as ATEX motors, available from TEC Motors of Worcestershire, United Kingdom, among other sources.

[0061] To reduce electrical noise/interference, such as when using a grid-based power source, the transformers (64A, 64B) can be adapted to convert the received power to a larger number of successive electrical phases/pulses. For example a transformer could receive and convert a three-phase source of power to a nine-phase, eighteen-pulse source of power for transmission to successive system components.

[0062] As such, the depicted power subsystem (16) is usable to reduce or eliminate conventional use of diesel engines to power high pressure fracturing pumps. Additionally, use of modular sets of components positioned on mobile trailers or similar transportable vehicles (48A, 48B) minimizes the number and length of cables and other conduits required to power each component, while also facilitating installation of each component. For example, all connections between the transformers (64A, 64B), VFDs (66A, 66B, 66C, 66D), motors (68A, 68B, 68C, 68D), and high pressure pumps (70A, 70B, 70C, 70D) can generally be permanently installed, such that the vehicles (48A, 48B) can be positioned at a desired location at an operational site, then engaged with a single cable (58A, 58B), thereby powering each of the components. Further, use of modular, movable sets of components reduces the footprint of the system while enabling flexible positioning of components, as needed, depending on the position of other objects at an operational site. In an embodiment, power generation components can be placed remote from other system components, such as the fracturing fluid addition subsystem (12), which reduces risk of ignition when flammable components (e.g., propane) are used in the fracturing fluid.

[0063] While Figure 1 depicts two transportable vehicles (48A, 48B), each having one transformer, two VFDs, two electrical motors, and two high pressure pumps thereon, it should be understood that any number of transportable vehicles can be used, and further, each transportable vehicle could include a single high pressure pump or three or more high pressure pumps without departing from the scope of the present disclosure. Additionally, while Figure 1 depicts a single transformer used in conjunction with two VFDs, two motors, and two high pressure pumps, any number of transformers could be used, or in an embodiment, a suitable voltage could be provided to the components of the power subsystem (16) directly, obviating the need for transformers on the transportable vehicles. Further, while Figure 1 depicts a single VFD used to actuate a single electrical motor, which in turn powers a single high pressure pump, in various embodiments, a VFD could actuate multiple motors, multiple VFDs could be used to actuate a single motor, a single motor could power multiple high pressure pumps, and/or multiple motors could power a single high pressure pump.

[0064] Positioning components of the power subsystem (16) in close proximity to one another, e.g., on transportable vehicles (48A, 48B) can enable other synergistic benefits to be obtained. For example, in an embodiment, air from one or more blowers used to cool the electric motors (68A, 68B, 68C, 68D) and/or maintain positive pressure therein could be channeled to the adjacent high pressure pumps (70A, 70B, 70C, 70D), e.g., by positioning each motor and associated high pressure pump in a single housing and/or connecting the housing of each motor to that of each associated pump via an air conduit. Air from the blowers could thereby dissipate/disperse any propane or other alkanes and/or other flammable materials proximate to the pumps during operation, thereby preventing accumulation of flammable materials in a concentration that could be ignited. In one embodiment, the coupling and/or shaft connecting the motors to respective high pressure pumps could be provided with fins, blades, and/or other similar protrusions, such that rotation of the shaft can circulate air proximate to the high pressure pumps, and/or blower air from the motors can facilitate rotation of the shaft via the fins/protrusions by adding rotational motive force thereto.

[0065] For example, Figure 2A depicts an embodiment of an electric-powered motor (72) having a blower (74) associated therewith, typically usable to provide air to the operative and/or moving parts of the motor (72), e.g., to cool the motor (72), represented by the air flowpath (76). A drive shaft (80) of the motor (72) is shown extending therefrom to engage an adjacent pump (78) (e.g., a high pressure pump usable in fracturing operations). Rotation and/or other types of movement of the drive shaft (80) as the motor (72) is powered can thereby actuate the pump (78). An air conduit (82) is shown extending between the motor (72) and the pump (78), such that air from the blower (76) can flow through the conduit

(82) to the pump (72), as indicated by the flowpath (84), e.g., for dissipating gas proximate thereto.

[0066] Figure 2B depicts an alternate embodiment in which the motor (72), blower (74), pump (78), and drive shaft (80) are shown. In the depicted embodiment, an air conduit (86) is circumferentially disposed around the drive shaft (80), such that air from the blower (74) that moves across the motor (72), as indicated by the flowpath (86), can pass through the conduit (86), as indicated by the flowpath (88), e.g., to dissipate gas proximate to the pump (78).

[0067] Figure 2C depicts an alternate embodiment in which the which the motor (72), blower (74), pump (78), and drive shaft (80) are shown, contained within a single housing (96). Air from the blower (74) that passes across the motor (72), as indicated by the flowpath (76), can therereby also flow proximate to the pump (78), as indicated by flowpaths (86A, 98B).

[0068] It should be understood that while Figures 2A through 2C depict three possible methods by which air from a blower associated with a motor can be circulated in proximity to a pump, any method for conveying air to the pump can be used without departing from the scope of the present disclosure, and any of the features depicted in Figures 2A through 2C are usable singularly or in combination.

[0069] Figure 3 depicts an embodiment in which the motor (72), blower (74), pump (78), and drive shaft (80) are shown, in which the drive shaft (80) includes multiple protrusions (90A, 90B) (e.g., fins, blades, etc.) extending therefrom. Air from the blower (74) can be provided, e.g,. to cool the motor (72), as indicated by flowpath (76). The air can then flow, as indicated by flowpath (100), to contact one or more protrusions (90A, 90B), thereby imparting motive force thereto, and subsequently, to the drive shaft (80), such that the flow of air can cause additional rotation of the drive shaft (80), as indicated by the arrows (102A, 102B). While only two protrusions (90A, 90B) are shown in Figure 3, any number and placement/configuration of protrusions can be used without departing from the scope of the present disclosure. Further, it should be understood that protrusions extending from the drive shaft can be used singularly or in combination with any of the features shown in Figures 2A through 2C.

[0070] Figure 4 depicts an embodiment in which the protrusions (90A, 90B) are themselves usable as an air-moving device. The motor (72), blower (74), pump (78), and drive shaft (80) are shown, in which the drive shaft (80) includes multiple protrusions (90A, 90B) extending therefrom. Movement of the drive shaft (80), e.g., imparted by the motor (72), as indicated by arrow (92), can thereby cause rotation of the protrusions (90A, 90B), which can be configured and/or oriented to circulate air proximate to the pump (78), as indicated by the flowpaths (94A, 94B).

[0071] Figure 5 depicts a diagrammatic side view of an embodiment of a VFD (104) usable within the scope of the present disclosure. It should be understood that while a VFD is depicted and described herein, the concept illustrated in Figure 5 is usable with any element of the system depicted in Figure 1. Specifically, during operations, it is possible for air at or proximate to the VFD (104) and/or other system components to become contaminated (e.g., with volatile gasses when using propane or similar components as a fracturing fluid, or with other fluids/gasses depending on the operations being performed). A region of contaminated air (108) is shown proximate to the top of the VFD (104), while generally clean air (110) (e.g., lacking contaminants heavier than air) is shown above the contaminated air (108). During use, it may be necessary for the VFD (104) to intake air (e.g., for cooling and/or for operation thereof), while the intake of propane, volatile components, and/or other contaminants would be undesirable. Figure 5 depicts an air conduit (106) (e.g., a "snorkel") extending from and/or otherwise engaged with the VFD (104) for communicating clean air (110) into the VFD (104), while isolating the VFD (104) from contaminated air.

[0072] In Figures 6-8 the motor/pump combination(s) (X11) comprise the electric-powered driver (X06) and the pump (X08).

[0073] Figure 6 depicts a diagrammatic view of an embodiment of an electrical pumping system (200) for supplying fracturing materials to a formation, usable within the scope of the present disclosure. Specifically, Figure 6 shows an embodiment in which individual VFDs (204) are used in conjunction with multiple motor/pump combinations (211) configured to operate at high pressure. As depicted in Figure 6, multiple systems, in which a single VFD (204) coupled with multiple motor/pump combinations (211), can be utilized together in order to flow fracturing materials into a single high pressure manifold (214), which then supplies the fracturing material to the formation (216). The embodiment of the electrical system exemplified in Figure 6 may be of particular benefit to a fracturing system in which the flowing of a high volume of fracturing materials into a formation at low pressure is desired. When the motor/pump combinations (211) are operating at low pressure, and therefore do not require a large amount of power to drive, a single VFD (204) may be used to drive multiple motor/pump combinations (211) at low pressure without nearing or exceeding its maximum output capacity. This high-rate, low-pressure system can be achieved by operating a plurality of motor/pump combinations (211) with each VFD (204), thereby increasing the number of pumps (208), and therefore the volume of fracturing material that may be transported by the system (200) at low pressure at any given moment.

[0074] Figure 7 depicts a diagrammatic view of an embodiment of an electrical pumping system (300) for supplying fracturing materials to a formation, usable within the scope of the present disclosure. Specifically, Figure 7 illustrates an embodiment wherein a single VFD (304) may be used to drive a single motor/pump combination (311) in order to allow for the flowing of fracturing materials into a formation (316) at high pressure. The use of a single VFD (304) for each motor/pump combination (311) enables the VFD (304) to apply all of its output capacity to a single motor/pump combination (311) thereby allowing for the pump (308) to operate at higher pressure than would be possible if the VFD (304) was configured to split its output across multiple motor/pump combinations (311) as depicted in Figure 6.

[0075] Figure 8 depicts a diagrammatic view of an embodiment of an electrical pumping system (400) for supplying fracturing materials to a formation, usable within the scope of the present disclosure. Specifically, Figure 8 shows an embodiment similar to that of Figure 7, wherein a single VFD (404) is used to drive a single motor/pump combination (411); however in the embodiment depicted in Figure 8 the VFD (404) is remote from the motor/pump combination (411). The embodiment depicted in Figure 8 is ideal for a fracturing project utilizing volatile fracturing materials, including but not limited to hydrocarbons, into a formation at high pressure. The configuration of a single VFD (404) driving a single motor/pump combination (411) allows for improved high pressure pumping (as described in the description of Figure 7). The removal of the VFD (404) component from physical proximity with the pump (408) and electrical motor (406) which the VFD (404) is being used to drive allows for additional safety, especially when the material being pumped is volatile, at high pressure, or some combination thereof. By providing physical separation between the VFD (404) and the volatile and/or high pressure fracturing material being manipulated, the risks associated with potential ignition sources are reduced. Specifically, in the event that the fracturing material is flammable and/or combustible (e.g. liquid propane or other hydrocarbons) the removal of the VFD (404) from proximity of the motor/pump combination (411) reduces the risk of the VFD (404) causing the ignition and/or combustion of any fracturing material that escapes from the motor/pump combination (411). This may be of particular importance when the volatile fracturing material is being pumped at high pressure due to the increased likelihood of both leaks in the pressure system and aerosolization of the fracturing material when it transitions from the high pressure present in the pressure system to the low ambient pressure. This configuration further allows for the reduction of costs since the VFD (404) is remote from the area where there is a possibility of interaction with volatile fracturing materials the VFD (404) itself would not have to be designed to be protected from the fire or explosion that could potentially affect the VFD (404) if it were located proximate to the motor/pump combination (411) that it is driving.

[0076] While various embodiments usable within the scope of the present disclosure have been described with emphasis, it should be understood that within the scope of the appended claims, the present invention can be practiced other than as specifically described herein.

CLAIMS

1. An electrical power system for providing fracturing materials to a formation at a pressure sufficient to stimulate the formation, the power system comprising:

a pump for pressurizing the fracturing material;

an electric motor coupled to the pump, together defining a pump/motor combination, the electric motor configured to provide mechanical energy to the pump for the purposes of actuating the pump; and

a variable frequency drive coupled to the electric motor and to a power source, wherein the variable frequency drive receives electricity from the power source, and wherein the variable frequency drive provides an electrical signal to the electric motor.

2. The system of claim 1, wherein the variable frequency drive is coupled to a single pump/motor combination.

3. The system of claim 1, wherein the variable frequency drive is coupled to a plurality of pump/motor combinations.

4. The system of claim 1, wherein the variable frequency drive is remote from physical proximity with the pump/motor combination.

5. The system of claim 1, wherein the fracturing material comprises a volatile material.

6. The system of clam 1, wherein the fracturing material comprises a non-volatile material.

7. The system of claim 6, wherein the variable frequency drive is located in physical proximity with a pump/motor combination.

8. The system of claim 1, wherein the variable frequency drive is located in physical proximity with a pump/motor combination.

9. The system of claim 1, wherein the electric motor is fire resistant.

10. The system of clam 1, wherein the electric motor is explosion resistant.

11. The system of claim 1, further comprising a mobile platform, wherein the pump, the electric motor, the variable frequency drive, or combinations thereof are positioned on the mobile platform.

12. The system of claim 1, further comprising a proppant addition subsystem adapted to enable a proppant to be added to the fracturing material.

13. The system of claim 1, further comprising a transformer coupled between the power source and the VFD, the transformer being configured to convert electricity received from the power source from a first voltage to a second voltage, wherein the second voltage is a voltage within a range useable by the VFD.

14. A method of electrically powering a system for providing a fracturing material to a formation at a pressure sufficient to stimulate the formation, the method comprising:

receiving into a variable frequency drive electricity from a power source;

outputting an electrical signal from the variable frequency drive;

inputting the electrical signal into an electrical-powered driver;

converting the electrical signal into mechanical energy through the use of the electrical-powered driver;

transferring the mechanical energy from the electrical-powered driver into a pump;

using the mechanical energy to actuate the pump in order to pressurize a volume of the fracturing material.

15. The method of claim 14, further comprising converting the electricity from a first voltage to a second

voltage prior to inputting the electricity into the variable frequency drive.

16. The method of claim 15, wherein the conversion of the electricity from the first voltage to the second voltage is achieved through the use of a transformer coupled between the power source and the variable frequency drive.

17. The method of claim 14, wherein at least a portion of the electrical signal is inputted into a plurality of electrical-powered drivers, and wherein each of the plurality of electrical-powered drivers outputs the second electrical signal to a pump.

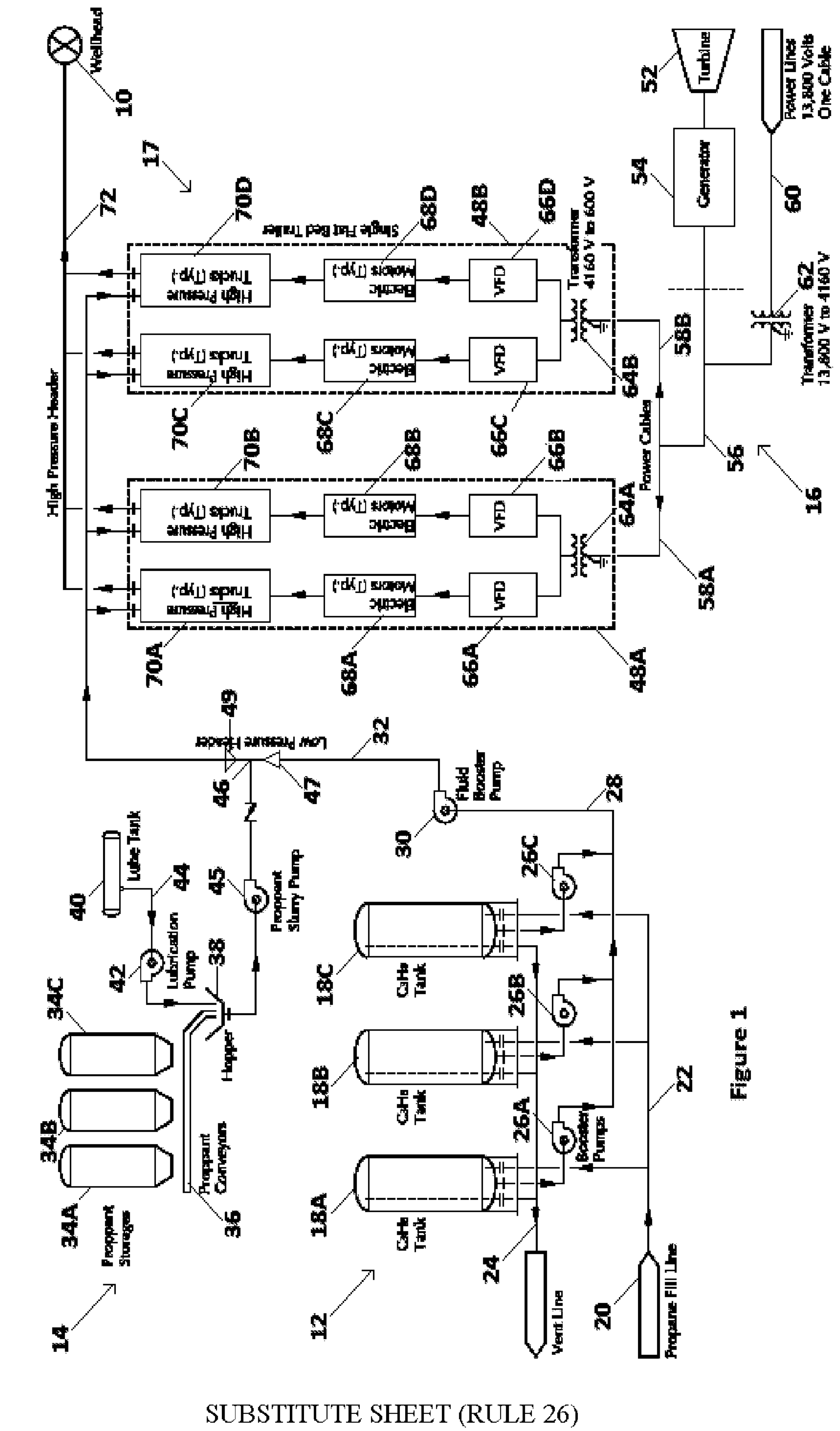
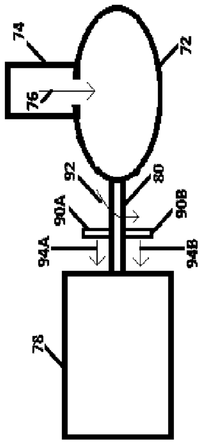


Figure 1

FIG 1

FIG 4



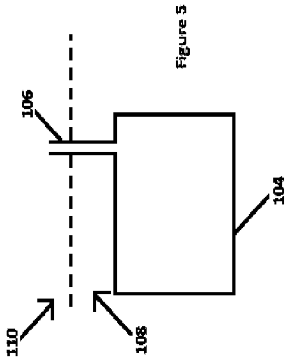
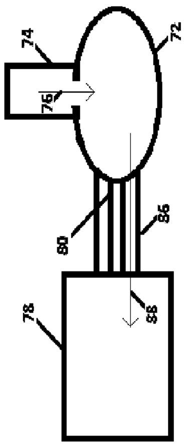


FIG 5

FIG 2B



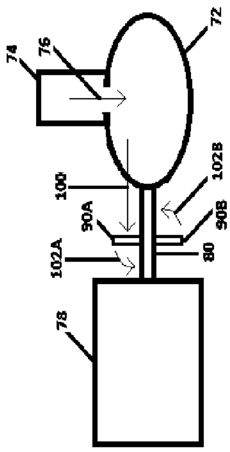
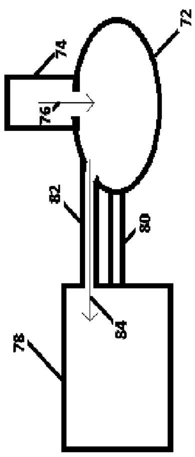


FIG 3

FIG 2A



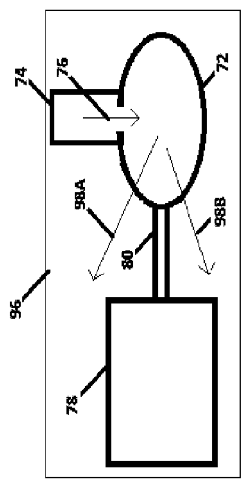


FIG 2C

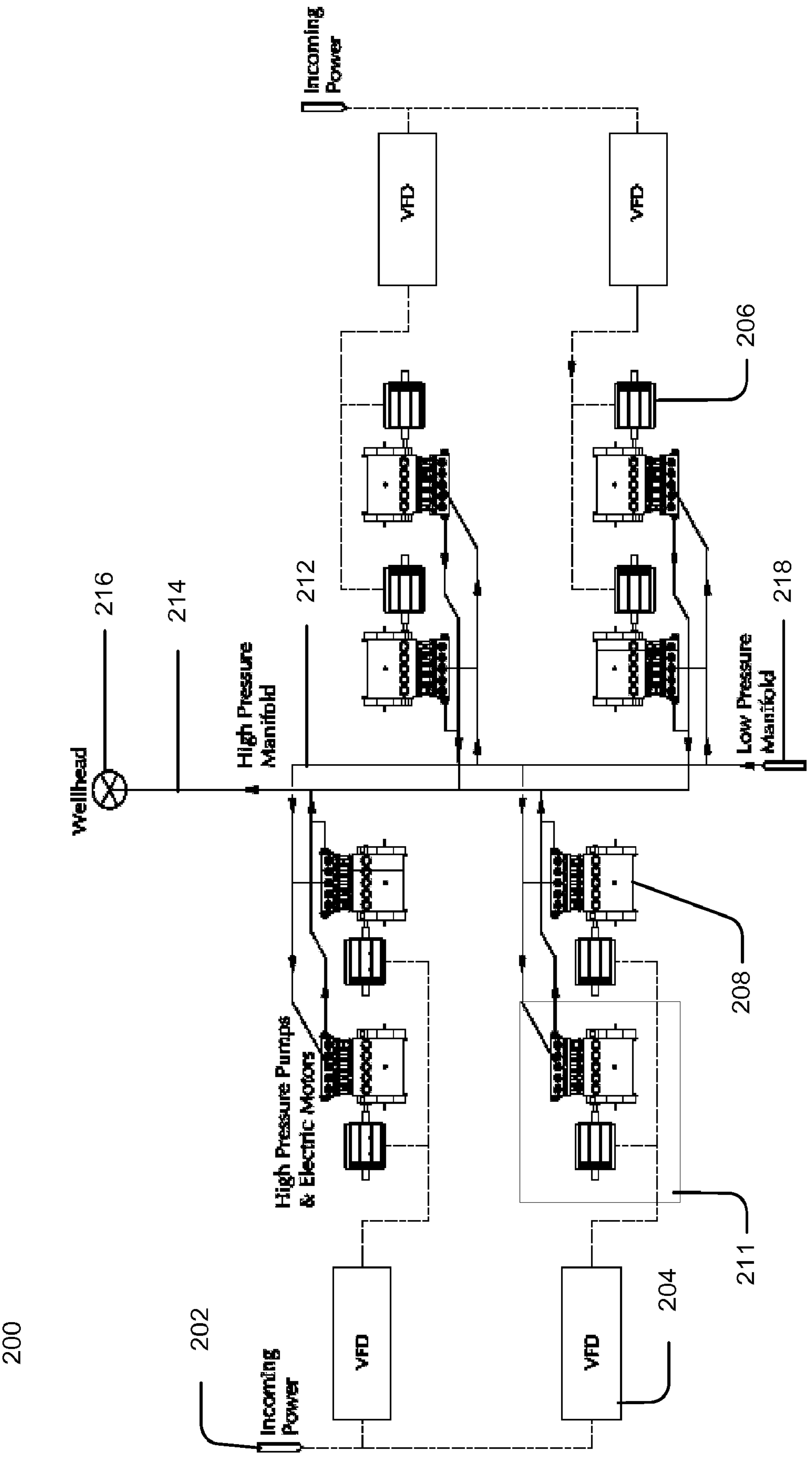

Incoming Power
VFD
VFD
206
216
214
212
218
Wellhead
High Pressure Manifold
Low Pressure Manifold
High Pressure Pumps & Electric Motors
208
211
200
202
204
Incoming Power
VFD
VFD

FIG 6

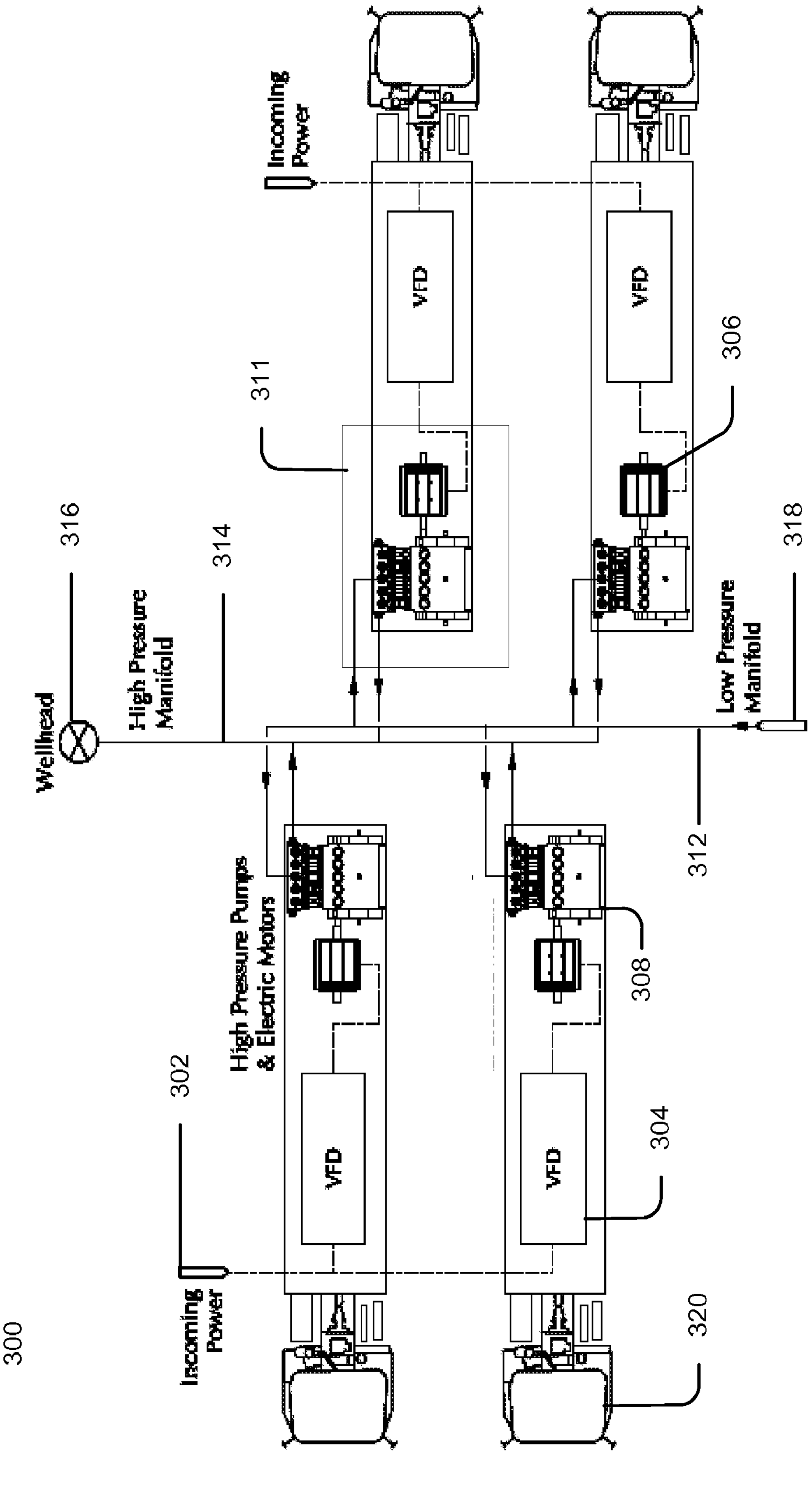

300
302
304
306
308
311
312
314
316
318
320
Wellhead
High Pressure Manifold
Low Pressure Manifold
High Pressure Pumps & Electric Motors
Incoming Power
Incoming Power
VFD
VFD
VFD
VFD

FIG 7

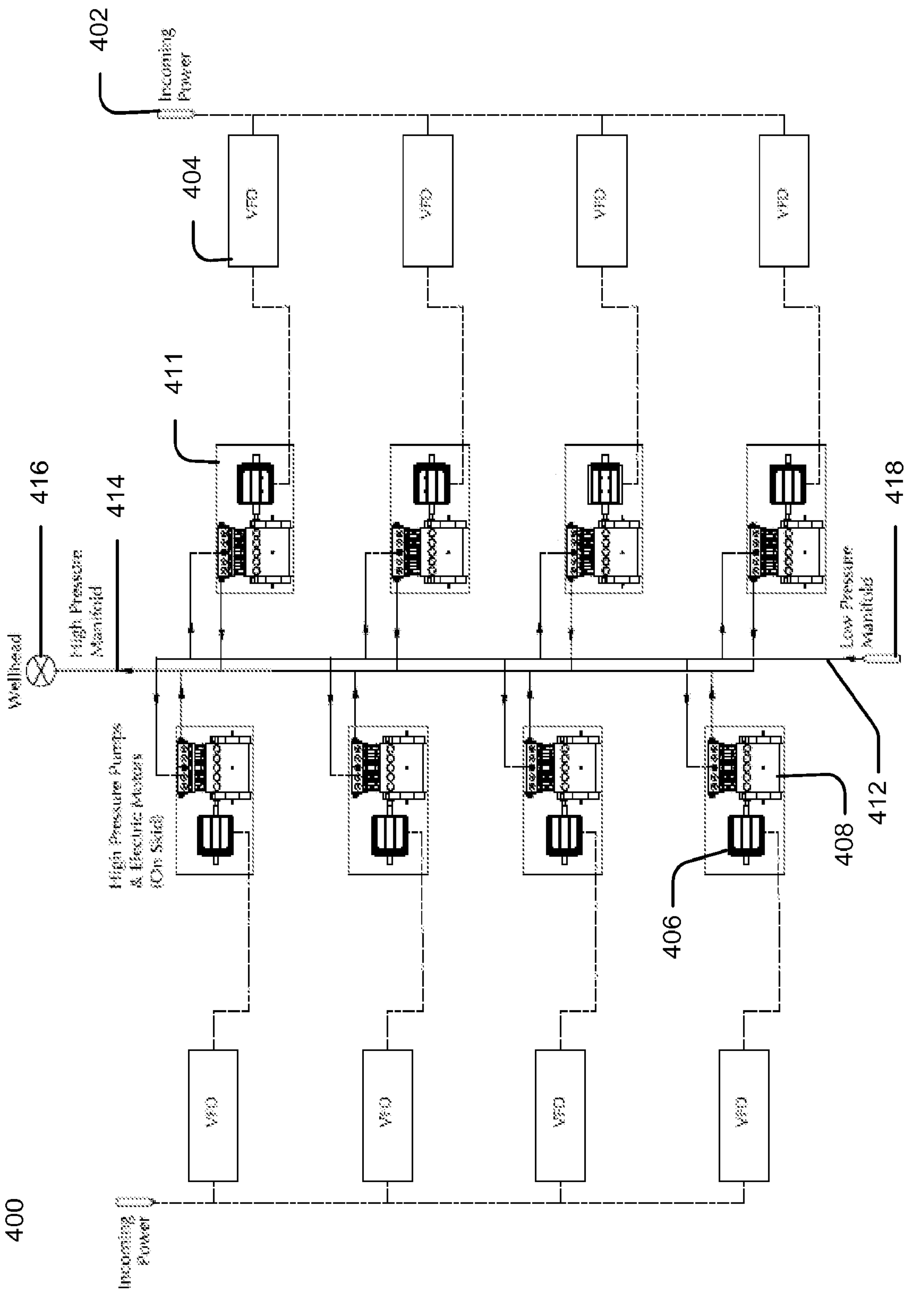

400
402
Incoming Power
Incoming Power
404
VFD
VFD
VFD
VFD
VFD
VFD
VFD
VFD
411
416
Wellhead
414
High Pressure Manifold
High Pressure Pumps & Electric Motors (On Skid)
418
Low Pressure Manifold
412
408
406

FIG 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/060082

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/25(2006.01)i, E21B 43/26(2006.01)i

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)
E21B 43/25; H02P 23/00; E21B 43/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: wellbore, fracturing system, pump, motor, power source, variable frequency drive, mobile platform, proppant, and signal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013-0306322 A1 (SANBORN et al.) 21 November 2013 See paragraphs [0010],[0029]-[0043] and figures 1-2.	1-13
A		14-17
A	US 2012-0255734 A1 (COLI et al.) 11 October 2012 See abstract, paragraphs [0009]-[0020] and figures 2-7.	1-17
A	US 2012-0085541 A1 (LOVE et al.) 12 April 2012 See abstract, paragraphs [0023]-[0031] and figures 2-6.	1-17
A	US 2007-0277982 A1 (SHAMPINE et al.) 06 December 2007 See paragraphs [0019]-[0044] and figures 1-6.	1-17
A	US 2012-0242273 A1 (HSIEH et al.) 27 September 2012 See paragraphs [0007]-[0010] and claim 10.	1-17

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

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"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

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