



US012392225B2

(12) **United States Patent**
Krippner et al.

(10) **Patent No.:** **US 12,392,225 B2**

(45) **Date of Patent:** **Aug. 19, 2025**

(54) **POWER MANAGEMENT AT A WELLSITE**

(56) **References Cited**

(71) Applicant: **Schlumberger Technology Corporation**, Sugar Land, TX (US)

U.S. PATENT DOCUMENTS

4,483,362 A 11/1984 Luginbuhl

4,593,763 A 6/1986 Burke

(Continued)

(72) Inventors: **Nick Paul Krippner**, Houston, TX (US); **James Arthur Zapico**, Houston, TX (US); **Mateo Garcia**, Houston, TX (US); **Carlos White**, Katy, TX (US)

FOREIGN PATENT DOCUMENTS

GB 2320733 A * 7/1998 E21B 33/0355

JP 2003286901 A 10/2003

(Continued)

(73) Assignee: **Schlumberger Technology Corporation**, Sugar Land, TX (US)

OTHER PUBLICATIONS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 194 days.

Pavkovic et al., "Oil drilling rig diesel power-plant fuel efficiency improvement potentials through rule-based generator scheduling and utilization of battery energy storage system", Energy Conversion and Management, vol. 121, 2016, pp. 194-211.

(Continued)

(21) Appl. No.: **17/218,762**

(22) Filed: **Mar. 31, 2021**

Primary Examiner — Lincoln D Donovan

Assistant Examiner — James G Yeaman

(74) *Attorney, Agent, or Firm* — Jeffrey D. Frantz

(65) **Prior Publication Data**

US 2021/0301630 A1 Sep. 30, 2021

Related U.S. Application Data

(60) Provisional application No. 63/002,574, filed on Mar. 31, 2020.

(51) **Int. Cl.**
E21B 41/00 (2006.01)
E21B 19/14 (2006.01)
(Continued)

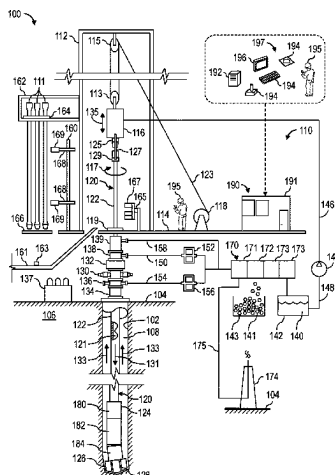
(52) **U.S. Cl.**
CPC **E21B 41/0085** (2013.01); **H02J 3/003** (2020.01); **H02J 3/32** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC E21B 41/0085; E21B 19/14; E21B 19/16;
E21B 21/08; H02J 3/003; H02J 3/32
See application file for complete search history.

(57) **ABSTRACT**

An example well construction system includes well construction equipment, a power supply system, and a control system. The well construction equipment performs well construction operations. The power supply system outputs electrical power to the well construction equipment. The power supply system includes an electrical generator unit and a control system including a processor and a memory storing a computer program code. The computer program code causes the control system to control an electrical power output level of the power supply system during the well construction operations. The computer program code also causes the control system to control operation of the well construction equipment during the well construction operations based on the electrical power output level during the well construction operations and an electrical power demand level of the well construction equipment during the well construction operations.

19 Claims, 6 Drawing Sheets



- * cited by examiner

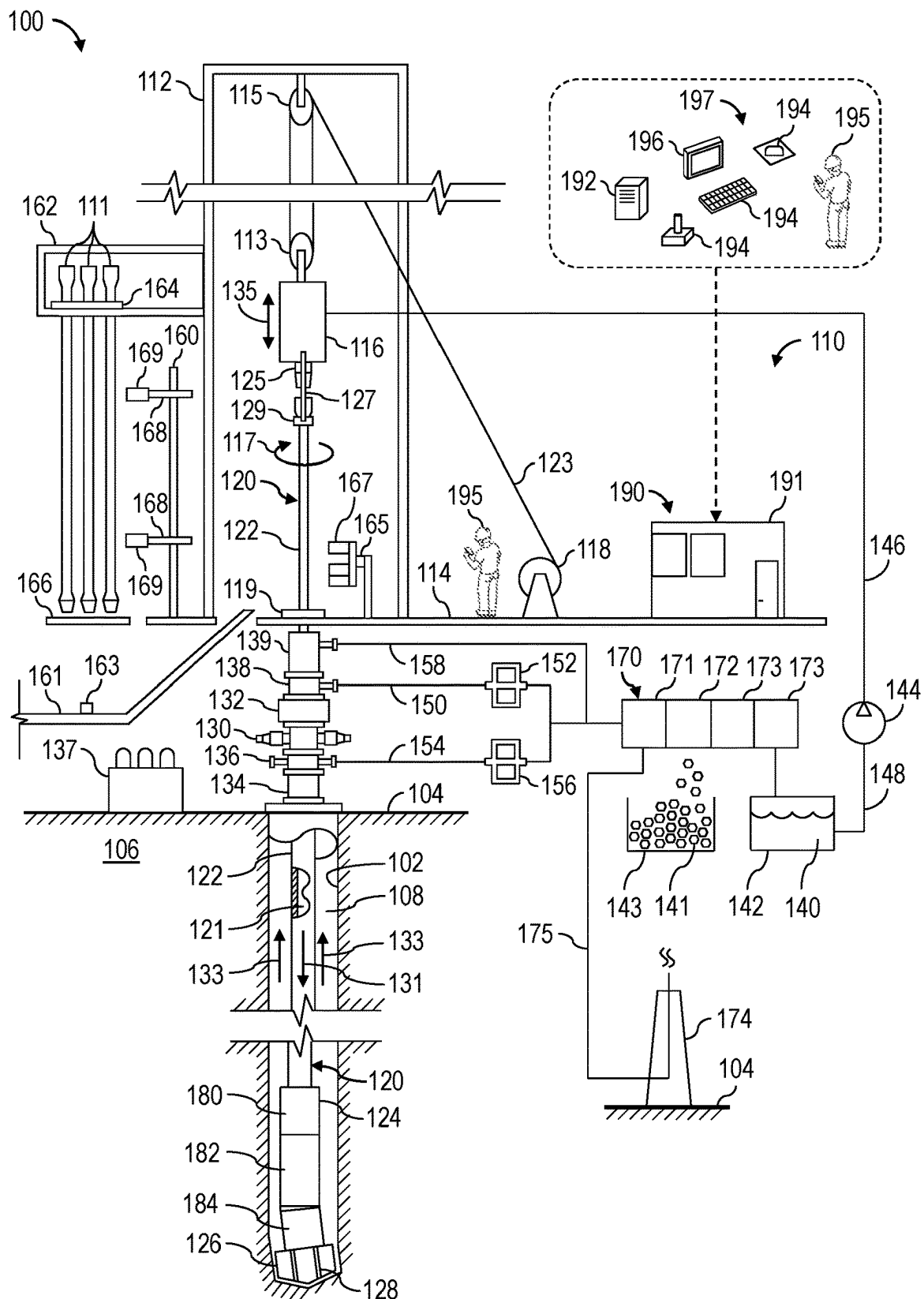


FIG. 1

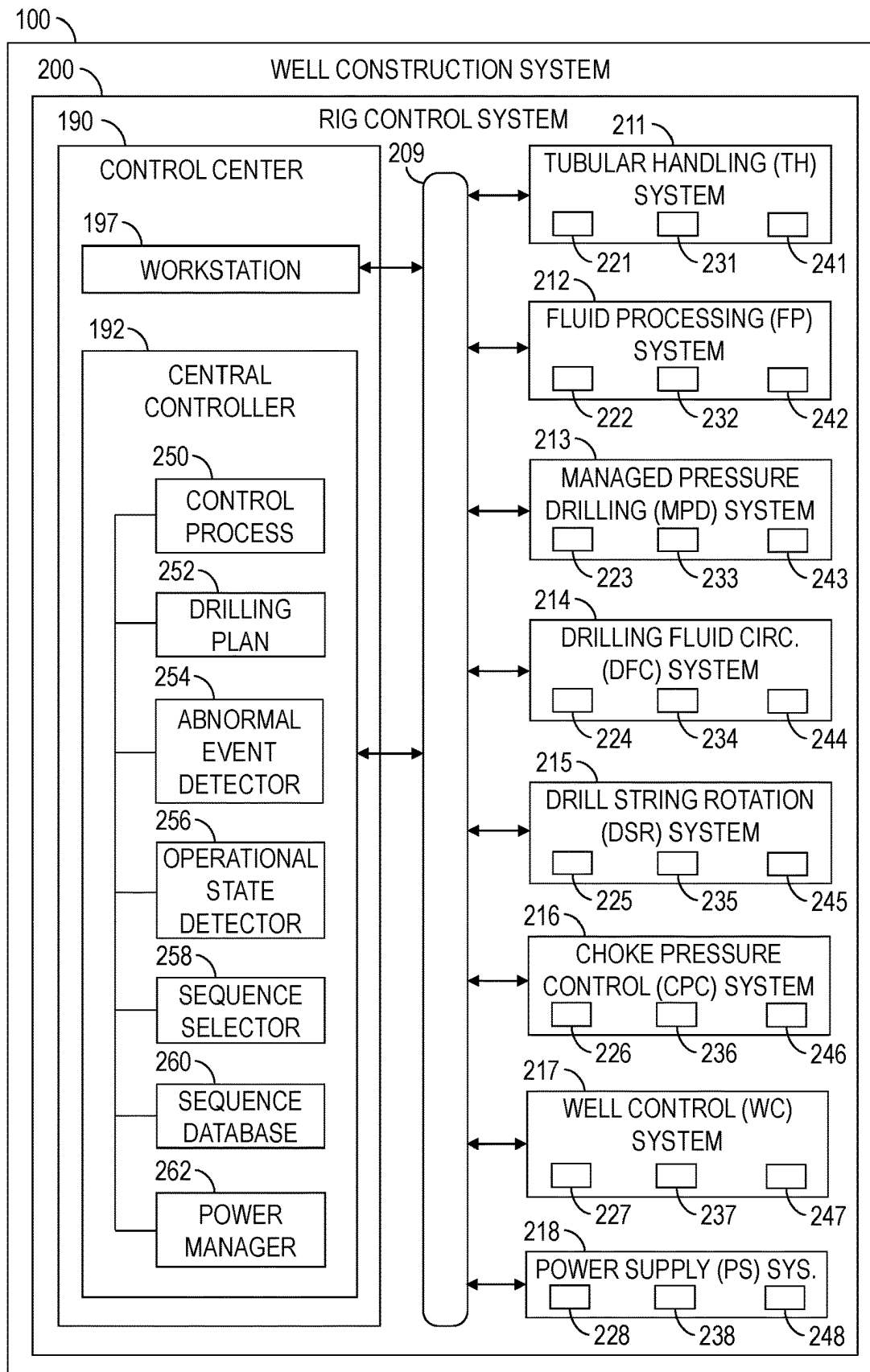


FIG. 2

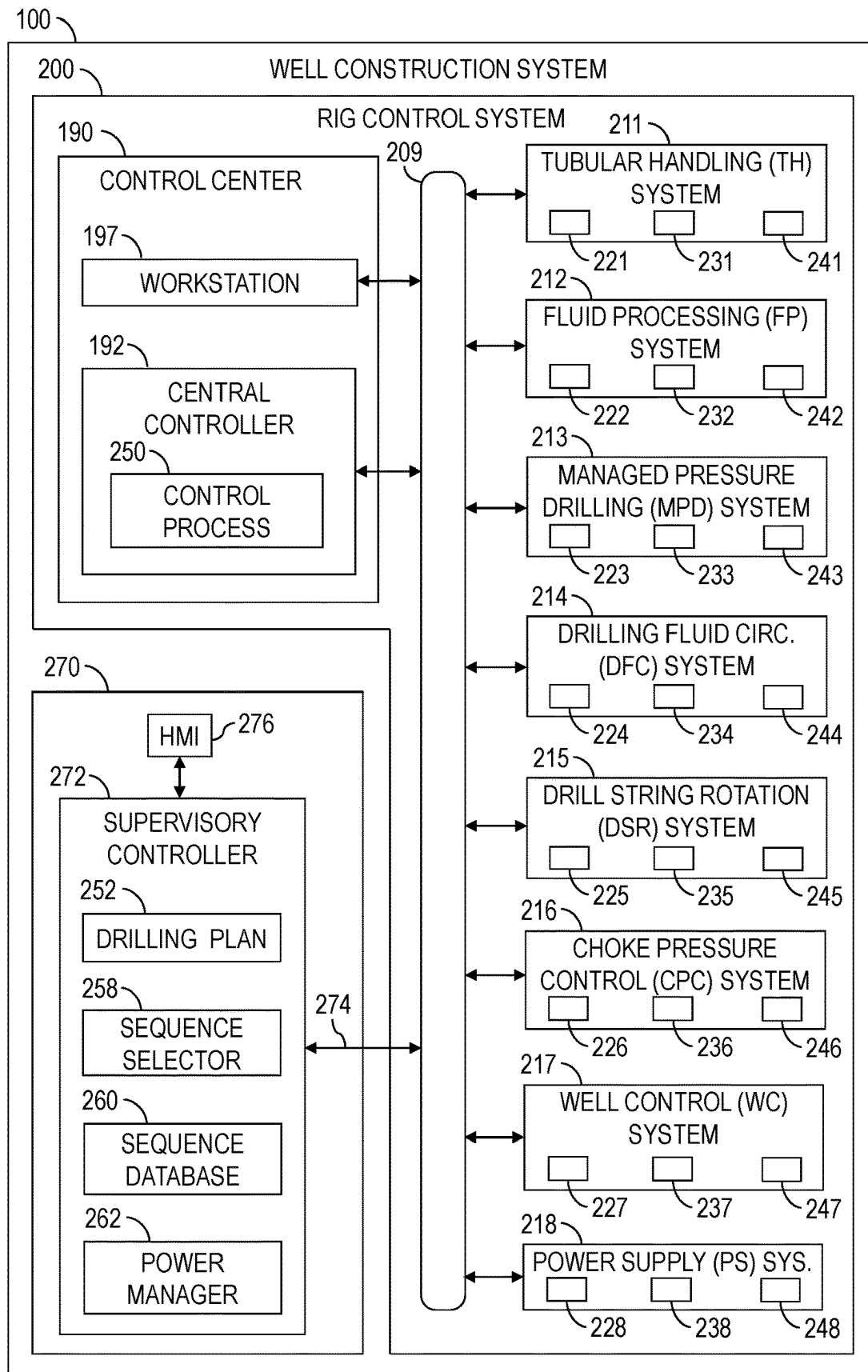
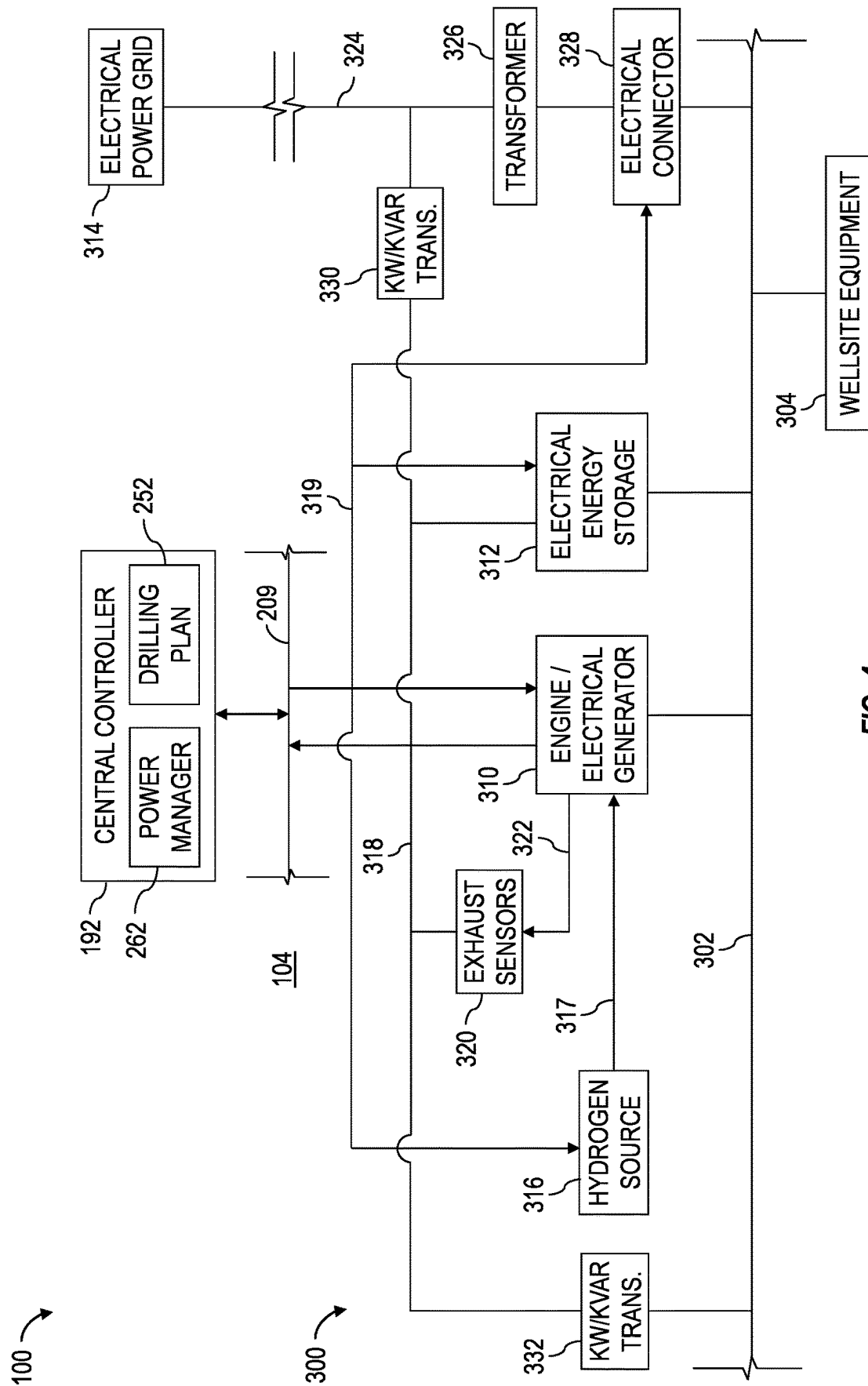


FIG. 3



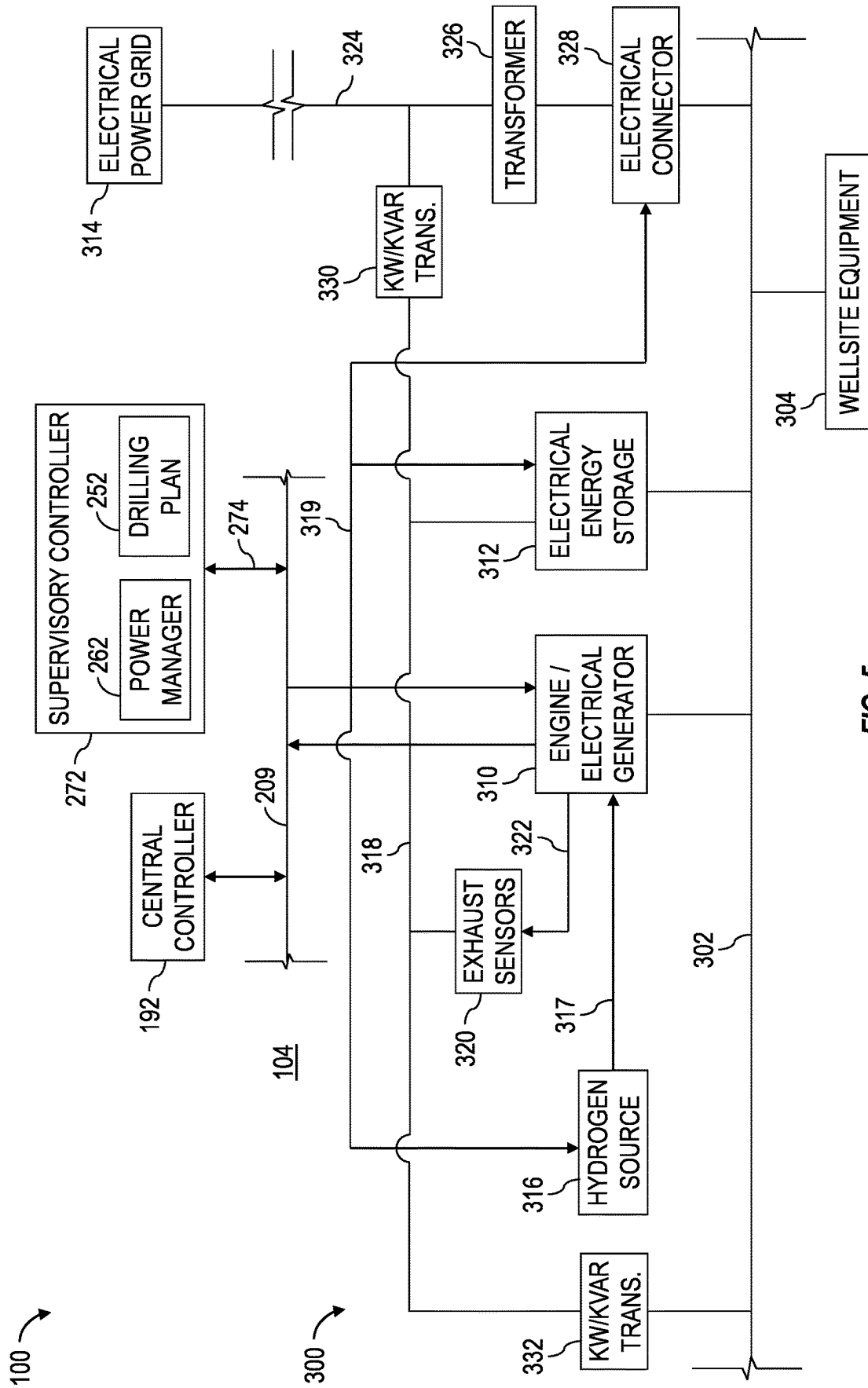


FIG. 5

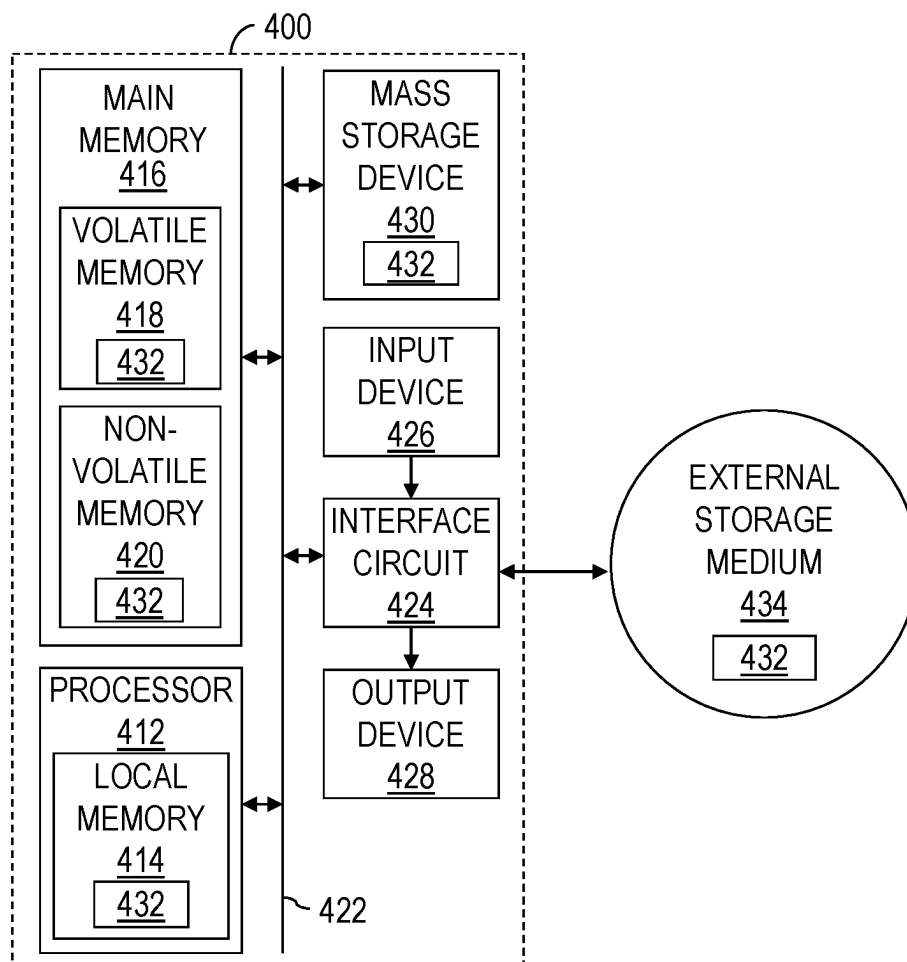


FIG. 6

1

POWER MANAGEMENT AT A WELLSITE**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims priority to and the benefit of U.S. Provisional Application No. 63/002,574, titled "POWER MANAGEMENT AT A WELLSITE," filed Mar. 31, 2020, the entire disclosure of which is hereby incorporated herein by reference.

BACKGROUND OF THE DISCLOSURE

Wells extend into the ground or ocean bed to facilitate recovery of natural deposits of oil, gas, and other materials that are trapped in subterranean rock formations. Well construction (e.g., drilling) operations may be performed at a wellsite by a well construction system (e.g., a drilling rig) having various surface and subterranean well construction equipment operating in a coordinated manner. For example, a drive mechanism, such as a top drive located at a wellsite surface, can be utilized to rotate and advance a drill string into a subterranean rock formation to drill a wellbore. The drill string may include a plurality of drill pipes coupled together and terminating with a drill bit. Length of the drill string may be increased by adding additional drill pipes while depth of the wellbore increases. Drilling fluid may be pumped from the wellsite surface down through the drill string to the drill bit. The drilling fluid lubricates and cools the drill bit and carries drill cuttings from the wellbore back to the wellsite surface. The drilling fluid returning to the surface may then be cleaned and again pumped through the drill string. The well construction equipment of the well construction system may be grouped into various subsystems, wherein each subsystem performs a different operation.

Combustion engine electrical generator units are typically utilized to output electrical power for operating the various well construction equipment. Efficiency of the generator units increases as load on the engine increases. For example, fuel efficiency of the generator units (e.g., diesel fuel generating units) may be optimal at engine loads ranging between, for example, about 50% and about 100%. Efficiency of the generator units is also relatively low during generator warm up periods, which may take several minutes.

Electrical power demand changes frequently and significantly (i.e., to a high degree) during different stages of the well construction operations. During such well construction operations, the generator units collectively output electrical power to match electrical power demand of the well construction equipment, regardless of efficiency. Thus, during stages of well construction operations requiring relatively low levels of electrical power, the generator units collectively operate at low efficiencies. Also, while operating at low efficiency rates, the generator units discharge gas and particulate emissions at relatively high rates. During stages of well construction operations requiring relatively high levels of electrical power, one or more additional generator units may be turned on to provide additional electrical power without permitting the additional generator units to properly warm up, resulting in the generator units operating at low efficiency rates and discharging gas and particulate emissions at relatively high rates.

SUMMARY OF THE DISCLOSURE

This summary is provided to introduce a selection of concepts that are further described below in the detailed

2

description. This summary is not intended to identify indispensable features of the claimed subject matter, nor is it intended for use as an aid in limiting the scope of the claimed subject matter.

5 The present disclosure introduces a well construction system that includes well construction equipment, a power supply system, and a control system. The well construction equipment performs well construction operations. The power supply system outputs electrical power to the well construction equipment. The power supply system includes an electrical generator unit, as well as a control system including a processor and a memory storing a computer program code. The computer program code, when executed by the processor, causes the control system to control an electrical power output level of the power supply system during the well construction operations. The computer program code, when executed by the processor, also causes the control system to control operation of the well construction equipment during the well construction operations based on the electrical power output level during the well construction operations and an electrical power demand level of the well construction equipment during the well construction operations.

The present disclosure also introduces a well construction system that includes well construction equipment that performs well construction operations, a power supply system that outputs electrical power to the well construction equipment, and a control system. The power supply system includes an electrical generator unit, as well as a control system having a processor and a memory storing a computer program code and a well construction plan. The well construction plan is indicative of planned tasks to be performed by the well construction equipment as part of the well construction operations to construct a planned well. The computer program code, when executed by the processor, causes the control system to control an electrical power output level of the power supply system based on the well construction plan.

The present disclosure also introduces an apparatus that includes a control system and an electrical energy storage unit. The control system is installable in association with a well construction rig. The well construction rig includes well construction equipment that performs well construction operations to construct a planned well at a wellsite. The well construction rig also includes electrical generator units that output electrical power to the well construction equipment. The control system is communicatively connectable with the electrical generator units via a communication network of the well construction rig. The control system includes a processing device and a memory storing a computer program code. The electrical energy storage unit is installable in association with the well construction rig, electrically connectable with the electrical generator units, and communicatively connectable with the control system via the communication network. The computer program code, when executed by the processor, causes the control system to control the electrical generator units. The computer program code, when executed by the processor, also causes the control system to control the electrical energy storage unit to cause the electrical energy storage unit to alternately store electrical power output by the electrical generator units and output the stored electrical power to the well construction equipment during the well construction operations.

The present disclosure also introduces an apparatus including a control system and a hydrogen gas source. The control system is installable in association with a well construction rig that includes well construction equipment

that performs well construction operations to construct a planned well at a wellsite. The well construction rig also includes electrical generator units that output electrical power to the well construction equipment. The control system is communicatively connectable with the electrical generator units via a communication network of the well construction rig. The control system includes a processing device and a memory storing a computer program code. The hydrogen gas source is installable in association with the well construction rig, fluidly connectable with each engine of the electrical generator units, and communicatively connectable with the control system via the communication network. The hydrogen gas source can output hydrogen gas into each engine. The computer program code, when executed by the processor, causes the control system to control the electrical generator units and control the hydrogen gas source to cause the hydrogen gas source to output the hydrogen gas into one or more of the engines.

These and additional aspects of the present disclosure are set forth in the description that follows, and/or may be learned by a person having ordinary skill in the art by reading the material herein and/or practicing the principles described herein. At least some aspects of the present disclosure may be achieved via means recited in the attached claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. 1 is a schematic side view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. 2 is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. 3 is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. 4 is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. 5 is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. 6 is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

DETAILED DESCRIPTION

It is to be understood that the following disclosure describes many example implementations for different aspects introduced herein. Specific examples of components and arrangements are described below to simplify the present disclosure. These are merely examples, and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for simplicity and clarity, and does not in itself dictate a relationship between the various implementations described herein. Moreover, the formation of a first feature over or on a second feature in the descrip-

tion that follows may include implementations in which the first and second features are formed in direct contact, and may also include implementations in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

Systems and methods (e.g., processes, operations) according to one or more aspects of the present disclosure may be utilized or otherwise implemented in association with an automated well construction system (i.e., well construction rig) at an oil and gas wellsite, such as for constructing a well (including drilling a wellbore) for extracting hydrocarbons (e.g., oil and/or gas) from a subterranean formation. However, one or more aspects of the present disclosure may be utilized or otherwise implemented in association with other automated systems in the oil and gas industry and other industries. For example, one or more aspects of the present disclosure may be implemented in association with wellsite systems for performing fracturing, cementing, acidizing, chemical injecting, and/or water jet cutting operations, among other examples. One or more aspects of the present disclosure may also be implemented in association with mining sites, building construction sites, and/or other work sites where automated machines or equipment are utilized.

FIG. 1 is a schematic view of at least a portion of an example implementation of a well construction system 100 according to one or more aspects of the present disclosure. The well construction system 100 represents an example environment in which one or more aspects of the present disclosure described below may be implemented. The well construction system 100 may be or comprise a well construction (e.g., drilling) rig and associated well construction equipment. Although the well construction system 100 is depicted as an onshore implementation, the aspects described below are also applicable or readily adaptable to offshore implementations.

The well construction system 100 is depicted in relation to a wellbore 102 formed by rotary and/or directional drilling from a wellsite surface 104 and extending into a subterranean formation 106. The well construction system 100 comprises or is associated with various well construction equipment (i.e., wellsite equipment), including surface equipment 110 located at the wellsite surface 104 and a drill string 120 suspended within the wellbore 102. The surface equipment 110 may include a mast, a derrick, and/or another support structure 112 disposed over a rig floor 114. The drill string 120 may be suspended within the wellbore 102 from the support structure 112. The support structure 112 and the rig floor 114 are collectively supported over the wellbore 102 by legs and/or other support structures (not shown).

The drill string 120 may comprise a bottom-hole assembly (BHA) 124 and means 122 for conveying the BHA 124 within the wellbore 102. The conveyance means 122 may comprise a plurality of interconnected tubulars, such as drill pipe, heavy-weight drill pipe (HWDP), wired drill pipe (WDP), tough logging condition (TLC) pipe, and drill collars, among other examples. The conveyance means 122 may instead comprise coiled tubing for conveying the BHA 124 within the wellbore 102. A downhole end of the BHA 124 may include or be coupled to a drill bit 126. Rotation of the drill bit 126 and the weight of the drill string 120 collectively operate to form the wellbore 102. The drill bit 126 may be rotated from the wellsite surface 104 and/or via a downhole mud motor 184 connected with the drill bit 126. The BHA 124 may also include various downhole devices and/or tools 180, 182.

5

The support structure 112 may support a driver, such as a top drive 116, operable to connect (perhaps indirectly) with an upper end of the drill string 120, and to impart rotary motion 117 and vertical motion 135 to the drill string 120, including the drill bit 126. However, another driver, such as a kelly and rotary table (neither shown), may be utilized instead of or in addition to the top drive 116 to impart the rotary motion 117 to the drill string 120. The top drive 116 and the connected drill string 120 may be suspended from the support structure 112 via a hoisting system or equipment, which may include a traveling block 113, a crown block 115, and a drawworks 118 storing a support cable or line 123. The crown block 115 may be connected to or otherwise supported by the support structure 112, and the traveling block 113 may be coupled with the top drive 116. The drawworks 118 may be mounted on or otherwise supported by the rig floor 114. The crown block 115 and traveling block 113 comprise pulleys or sheaves around which the support line 123 is reeved to operatively connect the crown block 115, the traveling block 113, and the drawworks 118 (and perhaps an anchor). The drawworks 118 may thus selectively impart tension to the support line 123 to lift and lower the top drive 116, resulting in the vertical motion 135. The drawworks 118 may comprise a drum, a base, and a prime mover (e.g., an electric motor) (not shown) operable to drive the drum to rotate and reel in the support line 123, causing the traveling block 113 and the top drive 116 to move upward. The drawworks 118 may be operable to reel out the support line 123 via a controlled rotation of the drum, causing the traveling block 113 and the top drive 116 to move downward.

The top drive 116 may comprise a grabber, a swivel (neither shown), elevator links 127 terminating with an elevator 129, and a drive shaft 125 operatively connected with a prime mover (e.g., an electric motor) (not shown), such as via a gear box or transmission (not shown). The drive shaft 125 may be selectively coupled with the upper end of the drill string 120 and the prime mover may be selectively operated to rotate the drive shaft 125 and the drill string 120 coupled with the drive shaft 125. Thus, during drilling operations, the top drive 116, in conjunction with operation of the drawworks 118, may advance the drill string 120 into the formation 106 to form the wellbore 102. The elevator links 127 and the elevator 129 of the top drive 116 may handle tubulars (e.g., drill pipes, drill collars, casing joints, etc.) that are not mechanically coupled to the drive shaft 125. For example, when the drill string 120 is being tripped into or out of the wellbore 102, the elevator 129 may grasp the tubulars of the drill string 120 such that the tubulars may be raised and/or lowered via the hoisting equipment mechanically coupled to the top drive 116. The grabber may include a clamp that clamps onto a tubular when making up and/or breaking out a connection of a tubular with the drive shaft 125. The top drive 116 may have a guide system (not shown), such as rollers that track up and down a guide rail on the support structure 112. The guide system may aid in keeping the top drive 116 aligned with the wellbore 102, and in preventing the top drive 116 from rotating during drilling by transferring reactive torque to the support structure 112.

The drill string 120 may be conveyed within the wellbore 102 through various fluid control devices disposed at the wellsite surface 104 on top of the wellbore 102 and perhaps below the rig floor 114. The fluid control devices may be operable to control fluid within the wellbore 102. The fluid control devices may include a blowout preventer (BOP) stack 130 for maintaining well pressure control and com-

6

prising a series of pressure barriers (e.g., rams) between the wellbore 102 and an annular preventer 132. The fluid control devices may also include a rotating control device (RCD) 138 mounted above the annular preventer 132. The fluid control devices 130, 132, 138 may be mounted on top of a wellhead 134. A power unit 137 (i.e., a BOP control or closing unit) may be operatively connected with one or more of the fluid control devices 130, 132, 138 and operable to actuate, drive, operate, or otherwise control one or more of the fluid control devices 130, 132, 138. The power unit 137 may be or comprise a hydraulic fluid power unit fluidly connected with the fluid control devices 130, 132, 138 and selectively operable to hydraulically drive various portions (e.g., rams, valves, seals) of the fluid control devices 130, 132, 138. The power unit 137 may comprise one or more hydraulic pumps actuated by electric motors and operable to pressurize hydraulic fluid for operating the fluid control devices 130, 132, 138 as described herein.

The well construction system 100 may further include a drilling fluid circulation system or equipment operable to circulate fluids between the surface equipment 110 and the drill bit 126 during drilling and other operations. For example, the drilling fluid circulation system may be operable to inject a drilling fluid from the wellsite surface 104 into the wellbore 102 via an internal fluid passage 121 extending longitudinally through the drill string 120. The drilling fluid circulation system may comprise a pit, a tank, and/or other fluid container 142 holding the drilling fluid 140 (i.e., drilling mud), and one or more mud pump units 144 (i.e., drilling fluid pumps) operable to move the drilling fluid 140 from the container 142 into the fluid passage 121 of the drill string 120 via a fluid conduit 146 extending from the pump units 144 to the top drive 116 and an internal passage extending through the top drive 116. Each pump unit 144 may comprise a fluid pump (not shown) operable to pump the drilling fluid 140 and a prime mover (e.g., an electric motor) (not shown) operable to drive the corresponding fluid pump. The fluid conduit 146 may comprise one or more of a pump discharge line, a stand pipe, a rotary hose, and a gooseneck connected with a fluid inlet of the top drive 116. The pumps 144 and the container 142 may be fluidly connected by a fluid conduit 148, such as a suction line.

During drilling operations, the drilling fluid may continue to flow downhole through the internal passage 121 of the drill string 120, as indicated by directional arrow 131. The drilling fluid may exit the BHA 124 via ports 128 in the drill bit 126 and then circulate uphole through an annular space 108 ("annulus") of the wellbore 102 defined between an exterior of the drill string 120 and the wall of the wellbore 102, such flow being indicated by directional arrows 133. In this manner, the drilling fluid lubricates the drill bit 126 and carries formation cuttings uphole to the wellsite surface 104. The returning drilling fluid may exit the annulus 108 via different fluid control devices during different stages or scenarios of well drilling operations. For example, the drilling fluid may exit the annulus 108 via a bell nipple 139, the RCD 138, or a ported adapter 136 (e.g., a spool, cross adapter, a wing valve, etc.) located below one or more rams of the BOP stack 130.

During normal drilling operations, the drilling fluid may exit the annulus 108 via the bell nipple 139 and then be directed toward drilling fluid reconditioning equipment 170 via a fluid conduit 158 (e.g., gravity return line) to be cleaned and/or reconditioned, as described below, before being returned to the container 142 for recirculation. During managed pressure drilling operations, the drilling fluid may

exit the annulus **108** via the RCD **138** and then be directed into a choke manifold **152** (e.g., a managed pressure drilling choke manifold) via a fluid conduit **150** (e.g., a drilling pressure control line). The choke manifold **152** may include at least one choke and a plurality of fluid valves (neither shown) collectively operable to control the flow through and out of the choke manifold **152**. Backpressure may be applied to the annulus **108** by variably restricting flow of the drilling fluid or other fluids flowing through the choke manifold **152**. The greater the restriction to flow through the choke manifold **152**, the greater the backpressure applied to the annulus **108**. The drilling fluid exiting the choke manifold **152** may then pass through the drilling fluid reconditioning equipment **170** before being returned to the container **142** for recirculation. During well pressure control operations, such as when one or more rams of the BOP stack **130** is closed, the drilling fluid may exit the annulus **108** via the ported adapter **136** and be directed into a choke manifold **156** (e.g., a rig choke manifold, well control choke manifold) via a fluid conduit **154** (e.g., rig choke line). The choke manifold **156** may include at least one choke and a plurality of fluid valves (neither shown) collectively operable to control the flow of the drilling fluid through the choke manifold **156**. Backpressure may be applied to the annulus **108** by variably restricting flow of the drilling fluid (and other fluids) flowing through the choke manifold **156**. The drilling fluid exiting the choke manifold **156** may then pass through the drilling fluid reconditioning equipment **170** before being returned to the container **142** for recirculation.

Before being returned to the container **142**, the drilling fluid returning to the wellsite surface **104** may be cleaned and/or reconditioned via the drilling fluid reconditioning equipment **170**, which may include one or more of liquid-gas (i.e., mud gas) separators **171**, shale shakers **172**, and other drilling fluid cleaning and reconditioning equipment **173**. The liquid-gas separators **171** may remove formation gases entrained in the drilling fluid discharged from the wellbore **102** and the shale shakers **172** may separate and remove solid particles **141** (e.g., drill cuttings) from the drilling fluid. The drilling fluid reconditioning equipment **170** may further comprise other equipment **173** operable to remove additional gas and finer formation cuttings from the drilling fluid and/or modify chemical and/or physical properties or characteristics (e.g., rheology, density, etc.) of the drilling fluid. For example, the drilling fluid reconditioning equipment **170** may include a degasser, a desander, a desilter, a centrifuge, a mud cleaner, and/or a decanter, among other examples. The drilling fluid reconditioning equipment **170** may further include chemical containers and mixing equipment collectively operable to mix or otherwise add selected chemicals to the drilling fluid returning from the wellbore **102** to modify chemical and/or physical properties or characteristics of the drilling fluid being pumped back into the wellbore **102**. Intermediate tanks/containers (not shown) may be utilized to hold the drilling fluid while the drilling fluid progresses through the various stages or portions **171**, **172**, **173** of the drilling fluid reconditioning equipment **170**. The cleaned and reconditioned drilling fluid may be transferred to the fluid container **142**, the solid particles **141** removed from the drilling fluid may be transferred to a solids container **143** (e.g., a reserve pit), and/or the removed gas may be transferred to a flare stack **174** via a conduit **175** (e.g., a flare line) to be burned or to a container (not shown) for storage and removal from the wellsite.

The surface equipment **110** may include a tubular handling system or equipment operable to store, move, connect, and disconnect tubulars (e.g., drill pipes) to assemble and

disassemble the conveyance means **122** of the drill string **120** during drilling operations. For example, a catwalk **161** may be utilized to convey tubulars from a ground level, such as along the wellsite surface **104**, to the rig floor **114**, permitting the elevator **129** to grab and lift the tubulars above the wellbore **102** for connection with previously deployed tubulars. The catwalk **161** may have a horizontal portion and an inclined portion that extends between the horizontal portion and the rig floor **114**. The catwalk **161** may comprise a skate **163** movable along a groove (not shown) extending longitudinally along the horizontal and inclined portions of the catwalk **161**. The skate **163** may be operable to convey (e.g., push) the tubulars along the catwalk **161** to the rig floor **114**. The skate **163** may be driven along the groove by a drive system (not shown), such as a pulley system or a hydraulic system. Additionally, one or more racks (not shown) may adjoin the horizontal portion of the catwalk **161**. The racks may have a spinner unit for transferring tubulars to the groove of the catwalk **161**. The tubular handling system may comprise a plurality of actuators collectively operable to move various portions of the tubular handling equipment to perform the methods and operations described herein. The actuators may be or comprise electric motors and/or hydraulic cylinders and rotary actuators. The hydraulic cylinders and rotary actuators may be powered by hydraulic power packs comprising hydraulic pumps actuated by electric motors to pressurize hydraulic fluid.

An iron roughneck **165** may be positioned on the rig floor **114**. The iron roughneck **165** may comprise a torquing portion **167**, such as may include a spinner and a torque wrench comprising a lower tong and an upper tong. The torquing portion **167** of the iron roughneck **165** may be moveable toward and at least partially around the drill string **120**, such as may permit the iron roughneck **165** to make up and break out connections of the drill string **120**. The torquing portion **167** may also be moveable away from the drill string **120**, such as may permit the iron roughneck **165** to move clear of the drill string **120** during drilling operations. The spinner of the iron roughneck **165** may be utilized to apply low torque to make up and break out threaded connections between tubulars of the drill string **120**, and the torque wrench may be utilized to apply a higher torque to tighten and loosen the threaded connections. The iron roughneck may comprise a plurality of actuators collectively operable to move various portions of the iron roughneck to perform the methods and operations described herein. The actuators may be or comprise electric motors.

A set of slips **119** may be located on the rig floor **114**, such as may accommodate therethrough the drill string **120** during tubular make up and break out operations and during the drilling operations. The slips **119** may be in an open position during drilling operations to permit advancement of the drill string **120**, and in a closed position to clamp the upper end (e.g., the uppermost tubular) of the drill string **120** to thereby suspend and prevent advancement of the drill string **120** within the wellbore **102**, such as during the make up and break out operations.

During drilling operations, the various well construction equipment of the well construction system **100** may progress through a plurality of coordinated operations (i.e., operational sequences) to drill or otherwise construct the wellbore **102**. The operational sequences may change based on a well construction plan, status of the well, status of the subterranean formation, stage of drilling operations (e.g., tripping, drilling, tubular handling, etc.), and type downhole tubulars (e.g., drill pipe) utilized, among other examples.

During drilling operations, the hoisting system lowers the drill string 120 while the top drive 116 rotates the drill string 120 to advance the drill string 120 downward within the wellbore 102 and into the formation 106. During the advancement of the drill string 120, the slips 119 are in an open position, and the iron roughneck 165 is moved away or is otherwise clear of the drill string 120. When the upper end of the drill string 120 (i.e., the upper end of the uppermost tubular of the drill string 120) connected to the drive shaft 125 is near the slips 119 and/or the rig floor 114, the top drive 116 ceases rotating and the slips 119 close to clamp the upper end of the drill string 120. The grabber of the top drive 116 then clamps the uppermost tubular connected to the drive shaft 125, and the drive shaft 125 rotates in a direction reverse from the drilling rotation to break out the connection between the drive shaft 125 and the uppermost tubular. The grabber of the top drive 116 may then release the uppermost tubular.

Multiple tubulars may be loaded on the rack of the catwalk 161 and individual tubulars may be transferred from the rack to the groove in the catwalk 161, such as by the spinner unit. The tubular positioned in the groove may be conveyed along the groove by the skate 163 until the box end of the tubular projects above the rig floor 114. The elevator 129 of the top drive 116 then grasps the protruding box end, and the drawworks 118 may be operated to lift the top drive 116, the elevator 129, and the new tubular.

The hoisting system then raises the top drive 116, the elevator 129, and the new tubular until the tubular is aligned with the upper portion of the drill string 120 clamped by the slips 119. The iron roughneck 165 is moved toward the drill string 120, and the lower tong of the torqueing portion 167 clamps onto the upper end of the drill string 120. The spinning system threadedly connects the lower end (i.e., pin end) of the new tubular with the upper end (i.e., box end) of the drill string 120. The upper tong then clamps onto the new tubular and rotates with high torque to complete making up the connection with the drill string 120. In this manner, the new tubular becomes part of the drill string 120. The iron roughneck 165 then releases and moves clear of the drill string 120.

The grabber of the top drive 116 may then clamp onto the drill string 120. The drive shaft 125 is brought into contact with the upper end of the drill string 120 (e.g., the box end of the uppermost tubular) and rotated to make up a connection between the drill string 120 and the drive shaft 125. The grabber then releases the drill string 120, and the slips 119 are moved to the open position. The drilling operations may then resume.

The tubular handling equipment may further include a tubular handling manipulator (THM) 160 disposed in association with a vertical pipe rack 162 for storing tubulars 111 (e.g., drill pipes, drill collars, drill pipe stands, casing joints, etc.). The vertical pipe rack 162 may comprise or support a fingerboard 164 defining a plurality of slots configured to support or otherwise hold the tubulars 111 within or above a setback 166 (e.g., a platform or another area) located adjacent to, along, or below the rig floor 114. The fingerboard 164 may comprise a plurality of fingers (not shown), each associated with a corresponding slot and operable to close around and/or otherwise interpose individual tubulars 111 to maintain the tubulars 111 within corresponding slots of the fingerboard 164. The vertical pipe rack 162 may be connected with and supported by the support structure 112 or another portion of the wellsite system 100. The fingerboard 164/setback 166 provide storage (e.g., temporary storage) of tubulars 111 during various operations, such as

during and between tripping out and tripping of the drill string 120. The THM 160 may comprise a plurality of actuators collectively operable to move various portions of the THM 160 to perform the methods and operations described herein. The actuators may be or comprise electric motors.

The THM 160 may be operable to transfer the tubulars 111 between the fingerboard 164/setback 166 and the drill string 120 (i.e., space above the suspended drill string 120). For example, the THM 160 may include arms 168 terminating with clamps 169, such as may be operable to grasp and/or clamp onto one of the tubulars 111. The arms 168 of the THM 160 may extend and retract, and/or at least a portion of the THM 160 may be rotatable and/or movable toward and away from the drill string 120, such as may permit the THM 160 to transfer the tubular 111 between the fingerboard 164/setback 166 and the drill string 120.

To trip out the drill string 120, the top drive 116 is raised, the slips 119 are closed around the drill string 120, and the elevator 129 is closed around the drill string 120. The grabber of the top drive 116 clamps the upper end of a tubular of the drill string 120 coupled to the drive shaft 125. The drive shaft 125 then rotates in a direction reverse from the drilling rotation to break out the connection between the drive shaft 125 and the drill string 120. The grabber of the top drive 116 then releases the tubular of the drill string 120, and the drill string 120 is suspended by (at least in part) the elevator 129. The iron roughneck 165 is moved toward the drill string 120. The lower tong clamps onto a lower tubular below a connection of the drill string 120, and the upper tong clamps onto an upper tubular above that connection. The upper tong then rotates the upper tubular to provide a high torque to break out the connection between the upper and lower tubulars. The spinning system then rotates the upper tubular to separate the upper and lower tubulars, such that the upper tubular is suspended above the rig floor 114 by the elevator 129. The iron roughneck 165 then releases the drill string 120 and moves clear of the drill string 120.

The THM 160 may then move toward the drill string 120 to grasp the tubular suspended from the elevator 129. The elevator 129 then opens to release the tubular. The THM 160 then moves away from the drill string 120 while grasping the tubular with the clamps 169, places the tubular in the fingerboard 164/setback 166, and releases the tubular for storage. This process is repeated until the intended length of drill string 120 is removed from the wellbore 102.

The surface equipment 110 of the well construction system 100 may also comprise a control center 190 from which various portions of the well construction system 100, such as the top drive 116, the hoisting system, the tubular handling system, the drilling fluid circulation system, the well control system, and the BHA 124, among other examples, may be monitored and controlled. The control center 190 may be located on the rig floor 114 or another location of the well construction system 100. The control center 190 may comprise a facility 191 (e.g., a room, a cabin, a trailer, etc.) containing a control workstation 197, which may be operated by rig personnel 195 (e.g., a driller or other human rig operator) to monitor and control various well construction equipment or portions of the well construction system 100. The control workstation 197 may comprise or be communicatively connected with a central controller 192 (e.g., a processing device, a computer, etc.), such as may be operable to receive, process, and output information to monitor operations of and provide control to one or more portions of the well construction system 100. For example, the central controller 192 may be communicatively con-

11

nected with the various surface and downhole equipment described herein, and may be operable to receive signals from and transmit signals to such equipment to perform various operations described herein. The central controller **192** may store executable computer program code, instructions, and/or operational parameters or set-points, including for implementing one or more aspects of methods and operations described herein. The central controller **192** may be located within and/or outside of the facility **191**. Although it is possible that the entirety of the central controller **192** is implemented within one device, it is also contemplated that one or more components or functions of the central controller **192** may be implemented across multiple devices, some or an entirety of which may be implemented as part of the control center **190** and/or located within the facility **191**.

The control workstation **197** may be operable for entering or otherwise communicating control data (e.g., commands, signals, information, etc.) to the central controller **192** and other equipment controller by the rig personnel **195**, and for displaying or otherwise communicating information from the central controller **192** to the rig personnel **195**. The control workstation **197** may comprise a plurality of human-machine interface (HMI) devices, including one or more input devices **194** (e.g., a keyboard, a mouse, a joystick, a touchscreen, etc.) and one or more output devices **196** (e.g., a video monitor, a touchscreen, a printer, audio speakers, etc.). Communication between the central controller **192**, the input and output devices **194**, **196**, and the various well construction equipment may be via wired and/or wireless communication means. However, for clarity and ease of understanding, such communication means are not depicted, and a person having ordinary skill in the art will appreciate that such communication means are within the scope of the present disclosure.

Well construction systems within the scope of the present disclosure may include more or fewer components than as described above and depicted in FIG. 1. Additionally, various equipment and/or subsystems of the well construction system **100** shown in FIG. 1 may include more or fewer components than as described above and depicted in FIG. 1. For example, various engines, electric motors, hydraulics, actuators, valves, and/or other components not explicitly described herein may be included in the well construction system **100**, and are within the scope of the present disclosure.

The present disclosure further provides various implementations of systems and/or methods for controlling one or more portions of the well construction system **100**. FIG. 2 is a schematic view of at least a portion of an example implementation of a drilling rig control system **200** (hereinafter "rig control system") for monitoring and controlling various well construction equipment of the well construction system **100** shown in FIG. 1. The rig control system **200** may comprise one or more features of the well construction system **100**, including where indicated by the same reference numerals. Accordingly, the following description refers to FIGS. 1 and 2, collectively.

The various pieces of well construction equipment described above and shown in FIGS. 1 and 2 may each comprise one or more actuators (e.g., combustion, hydraulic, and/or electrical) that, when operated, may cause the corresponding well construction equipment to perform intended actions (e.g., work, tasks, movements, operations, etc.). Each piece of well construction equipment may further carry or comprise one or more sensors disposed in association with a corresponding actuator or another portion of the piece of equipment. Each sensor may be communicatively con-

12

nected with a corresponding equipment controller and operable to generate sensor data (e.g., electrical sensor signals or measurements, feedback signals, feedback loop, etc.) indicative of an operational (e.g., mechanical, physical, etc.) status of the corresponding piece of well construction equipment or actuator of that piece of equipment, thereby permitting the operational status of the piece of equipment to be monitored by the equipment controller. The sensor data may be utilized by the equipment controller as feedback data, permitting operational control of the piece of well construction equipment and coordination with other well construction equipment.

The rig control system **200** may be in real-time communication with and utilized to monitor and/or control various portions, components, and equipment of the well construction system **100** described herein. The equipment of the well construction system **100** may be grouped into several subsystems, each operable to perform a corresponding operation and/or a portion of the well construction operations described herein. The subsystems may include a tubular handling (TH) system **211**, a fluid processing (FP) system **212**, a managed pressure drilling (MPD) system **213**, a drilling fluid circulation (DFC) system **214**, a drill string rotation system (DSR) system **215**, a choke pressure control (CPC) system **216**, a well pressure control (WC) system **217**, and a power supply (PS) system **218**.

The TH system **211** may include the support structure **112**, a tubular hoisting system (e.g., the drawworks **118**, the elevator links **127**, the elevator **129**, and the slips **119**), a tubular handling system or equipment (e.g., the catwalk **161**, the THM **160**, the setback **166**, and the iron roughneck **165**), and/or other tubular handling equipment. Accordingly, the TH system **211** may perform tubular handling and hoisting operations. The TH system **211** may also serve as a support platform for tubular rotation equipment and a staging ground for rig operations, such as connection make up and break out operations described above. The FP system **212** may include the drilling fluid reconditioning equipment **170**, the flare stack **174**, the containers **142**, **143**, and/or other equipment. Accordingly, the FP system **212** may perform fluid cleaning, reconditioning, and mixing operations. The MPD system **213** may include the RCD **138**, the power unit **137**, the choke manifold **152**, and/or other equipment. The DFC system **214** may comprise the pumps **144**, the drilling fluid container **142**, the bell nipple **139**, and/or other equipment collectively operable to pump and circulate the drilling fluid at the wellsite surface and downhole. The DSR system **215** may include the top drive **116** and/or the rotary table and kelly. The CPC system **216** may comprise the choke manifold **156**, the ported adapter **136**, and/or other equipment, and the WC system **217** may comprise the BOP stack **130**, the power unit **137**, and a BOP control station for controlling the power unit **137**. The PS system **218** may comprise various sources of electrical power operable to power the well construction equipment of the well construction system **100**, including the well construction equipment of the well construction subsystems **211-217**. The PS system **218** may also include various means for transferring and/or distributing electrical power and fuel to the well construction equipment and between various pieces of equipment of the PS system **218**, including electrical power conductors, electrical connectors, electrical relays, fluid conductors, fluid connectors, and fluid valves, among other examples. The sources of electrical power may include electric generators, electrical energy storage devices (e.g., batteries, capacitors, etc.), fuel storage devices, and a remote electrical power grid, among other examples. Each of the well construction

13

subsystems **211-218** may further comprise various communication equipment (e.g., modems, network interface cards, etc.) and communication conductors (e.g., cables), communicatively connecting the equipment (e.g., sensors and actuators) of each subsystem **211-218** with a central controller **192** and a control workstation **197**. Although the well construction equipment listed above and shown in FIG. 1 is associated with certain wellsite subsystems **211-218**, such associations are merely examples that are not intended to limit or prevent such well construction equipment from being associated with two or more wellsite subsystems **211-218** and/or different wellsite subsystems **211-218**.

The rig control system **200** may include various local controllers **221-228**, each operable to control various well construction equipment of a corresponding subsystem **211-218** and/or an individual piece of well construction equipment of a corresponding subsystem **211-218**. As described above, each well construction subsystem **211-218** includes various well construction equipment comprising corresponding actuators **241-248** for performing operations of the well construction system **100**. Each subsystem **211-218** may include various sensors **231-238** operable to generate sensor data (e.g., signals, information, measurements, etc.) indicative of operational status of the well construction equipment of each subsystem **211-218**. Each local controller **221-228** may output control data (e.g., commands, signals, information, etc.) to one or more actuators **241-248** to perform corresponding actions of a piece of equipment or subsystem **211-218**. Each local controller **221-228** may receive sensor data generated by one or more sensors **231-238** indicative of operational status of an actuator or another portion of a piece of equipment or subsystem **211-218**. Although the local controllers **221-228**, the sensors **231-238**, and the actuators **241-248** are each shown as a single block, it is to be understood that each local controller **221-228**, sensor **231-238**, and actuator **241-248** may be or comprise a plurality of local controllers, sensors, and actuators.

The sensors **231-238** may include sensors utilized for operation of the various subsystems **211-218** of the well construction system **100**. For example, the sensors **231-238** may include cameras, position sensors, speed sensors, acceleration sensors, pressure sensors, force sensors, temperature sensors, flow rate sensors, vibration sensors, electrical current sensors, electrical voltage sensors, resistance sensors, gesture detection sensors or devices, voice actuated or recognition devices or sensors, chemical sensors, exhaust sensors, and/or other examples. The sensor data may include signals, information, and/or measurements indicative of equipment operational status (e.g., on or off, percent load, up or down, set or released, etc.), drilling parameters (e.g., depth, hook load, torque, etc.), auxiliary parameters (e.g., vibration data of a pump), flow rate, temperature, operational speed, position, and pressure, among other examples. The acquired sensor data may include or be associated with a timestamp (e.g., date and/or time) indicative of when the sensor data was acquired. The sensor data may also or instead be aligned with a depth or other drilling parameter.

The local controllers **221-228**, the sensors **231-238**, and the actuators **241-248** may be communicatively connected with the central controller **192**. For example, the local controllers **221-228** may be in communication with the sensors **231-238** and actuators **241-248** of the corresponding subsystems **211-218** via local communication networks (e.g., field buses) (not shown) and the central controller **192** may be in communication with the subsystems **211-218** via a central communication network **209** (e.g., a data bus, a field bus, a wide-area-network (WAN), a local-area-network

14

(LAN), etc.). The sensor data generated by the sensors **231-238** of the subsystems **211-218** may be made available for use by the central controller **192** and/or the local controllers **221-228**. Similarly, control data output by the central controller **192** and/or the local controllers **221-228** may be automatically communicated to the various actuators **241-248** of the subsystems **211-218**, perhaps pursuant to predetermined programming, such as to facilitate well construction operations and/or other operations described herein. Although the central controller **192** is shown as a single device (i.e., a discrete hardware component), it is to be understood that the central controller **192** may be or comprise a plurality of equipment controllers and/or other electronic devices collectively operable to monitor and control operations (i.e., computational processes or methods) of the well construction system. The central controller **192** may be located within or form a portion of a control center **190**, although a portion of the central controller **192** may instead be external to the control center **190**.

The sensors **231-238** and actuators **241-248** may be monitored and/or controlled by corresponding local controllers **221-228** and/or the central controller **192**. For example, the central controller **192** may be operable to receive sensor data from the sensors **231-238** of the wellsite subsystems **211-218** in real-time, and to output real-time control data directly to the actuators **241-248** of the subsystems **211-218** based on the received sensor data. However, certain operations of the actuators **241-248** of each subsystem **211-218** may be controlled by a corresponding local controller **221-228**, which may control the actuators **241-248** based on sensor data received from the sensors **231-238** of the corresponding subsystem **211-218** and/or based on control data received from the central controller **192**.

The rig control system **200** may be a tiered control system, wherein control of the subsystems **211-218** of the well construction system **100** may be provided via a first tier of the local controllers **221-228** and a second tier of the central controller **192**. The central controller **192** may facilitate control of one or more of the subsystems **211-218** at the level of each individual subsystem **211-218**. For example, in the FP system **212**, sensor data may be fed into the local controller **242**, which may respond to control the actuators **232**. However, for control operations that involve multiple subsystems **211-218**, the control may be coordinated through the central controller **192** operable to coordinate control of well construction equipment of two, three, four, or more (or each) of the subsystems **211-218**. For example, coordinated control operations may include the control of downhole pressure during tripping. The downhole pressure may be affected by the DFC system **214** (e.g., pump rate), the MPD system **213** (e.g., position of the choke **152**), and the TH system **211** (e.g., tripping speed). Thus, when it is intended to maintain certain downhole pressure during tripping, the central controller **192** may output control data to two or more of the participating subsystems **211-218**.

As described above, the central controller **192** may control various operations of the subsystems **211-218** via analysis of sensor data from one or more of the wellsite subsystems **211-218** to facilitate coordinated control between the subsystems **211-218**. The central controller **192** may generate control data to coordinate operations of various well construction equipment of the subsystems **211-218**. The control data may include, for example, commands from rig personnel, such as turn on or turn off a pump, switch on or off a fluid valve, and update a physical property set-point, among other examples. The local controllers **221-228** may each include a fast control loop that directly obtains sensor

15

data and executes, for example, a control algorithm to generate the control data. The central controller **192** may include a slow control loop to periodically obtain sensor data and generate the control data.

The rig control system **200**, including the central controller **192** and the local controllers **221-228**, facilitates operation of the well construction equipment in an equipment focused manner, such as to maintain the choke pressure to a certain value or to rotate the drill string at a certain rotational speed. The rig control system **200** may also coordinate operations of certain pieces of equipment to achieve intended operations, such as to move a tubular from the fingerboard to the well center, break up a tubular stand from the well center, or rack an individual tubular back to the fingerboard. Each such operation utilizes coordinated control of multiple pieces of pipe handling equipment by the central controller **192**.

The central controller **192**, the local controllers **221-228**, and/or other controllers or processing devices (referred to hereinafter as “equipment controllers”) of the rig control system **200** may each or collectively be operable to receive and store machine-readable and executable program code instructions (e.g., computer program code, algorithms, programmed processes or operations, etc.) on a memory device (e.g., a memory chip) and then execute the program code instructions to run, operate, or perform a control process for monitoring and/or controlling the well construction equipment of the well construction system **100**.

The central controller **192** may run (i.e., execute) a control process **250** (e.g., a coordinated control process or another computer process) and each local controller **221-228** may run a corresponding control process (e.g., a local control process or another computer process, not shown). Two or more of the local controllers **221-228** may run their local control processes to collectively coordinate operations between well construction equipment of two or more of the subsystems **211-218**.

The control process **250** of the central controller **192** may operate as a mechanization manager of the rig control system **200**, coordinating operational sequences of the well construction equipment of the well construction system **100**. The well construction system **100** may instead be operated manually by rig personnel (e.g., a driller) via a control workstation **197**. The control workstation **197** may be utilized to monitor, configure, control, and/or otherwise operate one or more of the subsystems **211-218** by the rig personnel. The control workstation **197** may be communicatively connected with the central controller **192** and/or the local controllers **221-228** via the communication network **209** and operable to receive sensor data from the sensors **231-238** and transmit control data to the central controller **192** and/or the local controllers **221-228** to control the actuators **241-248**. Accordingly, the control workstation **197** may be utilized by the rig personnel to monitor and control the actuators **241-248** and other portions of the subsystems **211-218** via the central controller **192** and/or local controllers **221-228**.

During manual operation, the rig personnel may operate as the mechanization manager of the rig control system **200** by manually coordinating operations of various well construction equipment, such as to achieve an intended operational status (or drilling state) of the well construction operations, including tripping in or drilling at an intended rate of penetration (ROP). The control process of each local controller **221-228** may facilitate a lower (e.g., basic) level of control within the rig control system **200** to operate a corresponding piece of well construction equipment or a

16

plurality of pieces of well construction equipment of a corresponding subsystem **211-218**. Such control process may facilitate, for example, starting, stopping, and setting or maintaining an operating speed of a piece of well construction equipment. During manual operation of the well construction system **100**, rig personnel manually controls the individual pieces of well construction equipment to achieve the intended operational status of each piece of well construction equipment.

The control process **250** of the central controller **192** may output control data directly to the actuators **241-248** to control the well construction operations. The control process **250** may also or instead output control data to the control process of one or more local controllers **221-228**, wherein each control process of the local controllers **221-228** may then output control data to the actuators **241-248** of the corresponding subsystem **211-218** to control a portion of the well construction operations performed by that subsystem **211-218**. Thus, the control processes of equipment controllers (e.g., central controller **192**, local controllers **221-228**) of the rig control system **200** individually and collectively perform monitoring and control operations described herein, including monitoring and controlling well construction operations. The program code instructions forming the basis for the control processes described herein may comprise rules (e.g., algorithms) based on the laws of physics for drilling and other well construction operations.

Each control process being run by an equipment controller of the rig control system **200** may receive and process (i.e., analyze) sensor data from the sensors **231-238** according to the program code instructions, and generate control data (i.e., control signals or information) to operate or otherwise control the actuators **241-248** of the well construction equipment. Equipment controllers within the scope of the present disclosure can include, for example, programmable logic controllers (PLCs), industrial computers (IPCs), personal computers (PCs), soft PLCs, variable frequency drives (VFDs) and/or other controllers or processing devices operable to store and execute program code instructions, receive sensor data, and output control data to cause operation of the well construction equipment based on the program code instructions, sensor data, and/or control data.

The central controller **192** may be operable to receive and store machine-readable and executable program code instructions on a memory device and then execute such program code instructions to run, operate, or perform a power manager **262** (e.g., a power control process, a power management process, or another computer process) operable to monitor and control the PS system **218** of the well construction system **100**. The program code instructions forming the basis for the power manager **262** described herein may comprise or be based on, for example, optimum efficiency performance curves or data of the various pieces of equipment forming the PS system **218**. The power manager **262** run on the central controller **192** may operate to monitor and control generation and distribution of electrical power performed by the PS system **218**. The power manager **262** may receive and process (i.e., analyze) sensor data from the sensors **238** according to the program code instructions to monitor performance of the PS system **218**, and generate control data (i.e., control signals or information) to operate or otherwise control the actuators **248** of the PS system **218** thereby controlling operations of the PS system **218**. The power manager **262** may output control data directly to the actuators **248** to control the generation and distribution of electrical power. The power manager **262** may also or instead output control data to one or more local controllers

228, wherein each of the local controllers 228 may then output control data to the actuators 248 of the PS system 218 to control a portion of the power generation and distribution operations performed by the PS system 218. The power manager 262 may also or instead output control data to the actuators 248 and/or one or more local controllers 228 via the control process 250. The electrical actuators 248 may comprise one or more of electrical motors, linear actuators, magnetic coils, switches, and relays, among other examples.

The central controller 192 may comprise a memory device operable to receive and store a well construction plan 252 (e.g., a drilling plan) for drilling and/or otherwise constructing a planned well. The well construction plan 252 may include well specifications, operational parameters, and other information indicative of the planned well and the well construction equipment of the well construction system 100. For example, the well construction plan 252 may include properties of the subterranean formation through which the planned well is to be drilled and otherwise constructed, the path (e.g., direction, curvature, orientation, etc.) along which the planned well is to be formed through the formation, the depth (e.g., true vertical depth (TVD) and/or measured depth (MD)) of the planned well, operational specifications (e.g., power output, weight, torque capabilities, speed capabilities, dimensions, size, etc.) of the well construction equipment (e.g., top drive, mud pumps, 144, downhole mud motor 184, etc.) that is planned to be used to construct the planned well, and/or specifications (e.g., diameter, length, weight, etc.) of tubulars (e.g., drill pipe) that are planned to be used to construct the planned well. The well construction plan 252 may include knowledge (e.g., efficiency of various parameters) learned from offset wells that have been drilled. Optimal parameters associated with the offset wells may then be used as the recommended parameters in a current well construction plan 252. The knowledge learned from the offset wells, including operation limits, such as maximum WOB, top drive speed (RPM), ROP, and/or tripping speed versus depth, may be applied and used as an operation limit within the well construction plan 252.

The well construction plan 252 may further include well construction operations schedule (e.g., order and/or time of well construction operations) for a plurality of planned well construction tasks (i.e., well construction objectives) that are intended to be achieved to complete the well construction plan 252. Each planned task may comprise a plurality of operational sequences and may be performed by the well construction equipment to construct the planned well. A planned task may be or comprise drilling a predetermined portion or depth of the planned well, completing a predetermined portion or stage of drilling operations, drilling through a predetermined section of the subterranean formation, and performing a predetermined plurality of operational sequences, among other examples. Each operational sequence may comprise a plurality or sequence of physical (i.e., mechanical) operations (i.e., actions) performed by various pieces of well construction equipment. Example operational sequences may include operations of one or more pieces of the well construction equipment of the well construction system 100 described above in association with FIG. 1.

The well construction plan 252 may further include planned operational parameters of the well construction equipment during each planned stage, portion, sequence, task, and/or operation of the well construction operations, such as WOB, RPM, and ROP as a function of wellbore depth. The well construction plan 252 may further include a planned electrical power demand profile (or schedule)

indicative of electrical power demand for performing or otherwise associated with each planned stage, portion, sequence, task, and/or operation of the well construction operations contained in the well construction plan 252. Thus, the planned electrical power demand profile may be or comprise a schedule (e.g., sequence or order) of expected electrical power demand levels for predetermined pieces of well construction equipment that are to be met to perform each planned stage, portion, sequence, task, and/or operation of the well construction operations. The planned electrical power demand profile may comprise information indicative of planned generation and/or distribution of electrical power generated by one or more pieces of electrical power generating equipment of the PS system 218 to the various well construction equipment of the well construction system 100, including the well construction equipment of the subsystems 211-218, such as to facilitate performance of the well construction operations pursuant to the well construction plan 252.

The information forming of otherwise from the well construction plan 252 may originate or be delivered in a paper form, whereby rig personnel manually input such information into the central controller 192. However, the information forming the well construction plan 252 may originate or be delivered in digital format, such that it can be directly loaded to or saved by a memory device of the central controller 192. The well construction plan 252 may be executed or analyzed programmatically by the control process 250 and/or the power manager 262 of the central controller 192 without human intervention. The memory device storing the well construction plan 252 may be or form a portion of the central controller 192, or the memory device storing the well construction plan 252 may be communicatively connected with the central controller 192. The control process 250 and/or the power manager 262 may analyze the well construction plan 252 and generate or output control data to the local controllers 221-228 or directly to the actuators 241-248 to control the well construction equipment to cause, facilitate, or otherwise implement one or more aspects of methods and operations described herein.

An equipment controller of the rig control system 200 for controlling the well construction system 100 may be operable to automate the well construction equipment to perform well construction operations and change such well construction operations as operational parameters of the well construction operations change and/or when an abnormal event (e.g., state, condition, etc.) is detected during the well construction operations. An equipment controller may be operable to detect an abnormal event based on the sensor data received from the sensors 231-238 and cause the predetermined operations to be performed or otherwise implemented to stop or mitigate the abnormal event or otherwise in response to the abnormal event, without manual control of the well construction equipment by the rig personnel via the control workstation 197. For example, an equipment controller may be operable to make decisions related to selection of actions or sequences of operations that are to be implemented during the well construction operations and/or the manner (e.g., speed, torque, mechanical power, electrical power, etc.) in which such selected operational sequences are to be implemented to stop or mitigate a detected abnormal event. An equipment controller may be further operable to receive and store information that may be analyzed by the control process 250 to facilitate the equipment controller to detect the abnormal event, and select and implement the operational sequences to stop or mitigate the abnormal event.

The central controller **192** may be operable to receive and store machine-readable and executable program code instructions on a memory device and then execute such program code instructions to run, operate, or perform an abnormal event detector **254** (e.g., an abnormal event detecting computer process), which may be operable to analyze or otherwise process the sensor data received from the sensors **231-238** and detect an abnormal event (e.g., status, condition, etc.) experienced by or otherwise associated with one or more pieces of well construction equipment, and/or an abnormal event experienced by or otherwise associated with a wellbore (e.g., the wellbore **102** shown in FIG. **1**). The abnormal event detector **254** may be operable to detect the abnormal events based on the sensor data and output abnormal event data indicative of the detected abnormal event. One or more of the local controllers **221-228** may also execute program code instructions to execute a corresponding abnormal event detector **254** to detect a local abnormal event. The local controllers **221-228** may then transmit data indicative of the local abnormal event to the central controller **190** for analysis. One or more of the processes of the central controller **192** may then re-plan well construction tasks, operational sequences, and other processes based on the detected abnormal events or otherwise based on the condition of the well and/or the well construction equipment.

For example, an abnormal event may be or comprise an abnormal operational surface event experienced by surface equipment (e.g., the surface equipment **110** shown in FIG. **1**) and/or an abnormal operational downhole event experienced by a drill string (e.g., the drill string **120** shown in FIG. **1**). An example abnormal operational downhole event may include stick-slip, axial vibrations, lateral vibrations, rotational vibrations, and stuck drill pipe. The abnormal event may instead be or comprise an abnormal downhole fluid event experienced by a downhole fluid, such as wellbore fluid (e.g., drilling fluid, formation fluid, fracturing fluid, etc.) within the wellbore, and/or formation fluid within a subterranean formation (e.g., the subterranean formation **106** shown in FIG. **1**) through which the wellbore extends. An example abnormal downhole fluid event may include underpressure of the formation fluid, overpressure of the formation fluid, gains of the wellbore fluid, and losses of the wellbore fluid.

The central controller **192** may be operable to receive and store machine-readable and executable program code instructions on a memory device and then execute such program code instructions to run, operate, or perform an operational state detector **256** (e.g., an operational state detecting computer process), which may be operable to analyze or otherwise process the sensor data received from the sensors **231-238** and detect a state (e.g., a status, a stage, etc.) of the well construction operations that the well construction system **100** is performing. The operational state detector **256** may then output operational state data indicative of the operational state of the well construction system **100**. Operational states of the well construction system **100** may comprise, for example, drilling, tripping, circulating, and reaming, among others.

The central controller **192** may be operable to receive and store machine-readable and executable program code instructions on a memory device and then execute the program code instructions to run, operate, or perform an operational sequence selector **258** (e.g., an operational sequence selecting computer process) operable to select and output an operational sequence (e.g., a plurality or series of physical or mechanical operations, actions, or movements)

and an electrical power demand profile associated with the selected operational sequence to be performed by the well construction equipment. Thus, an operational sequence selected by the sequence selector **258** may include or comprise an electrical power demand profile associated with the physical or mechanical operations specified in the selected operational sequence. The operational sequence selector **258** (or generator) may be operable to receive and analyze or otherwise process various data to select (or generate) the operational sequence. For example, the operational sequence selector **258** may be operable to receive and analyze the well construction plan **252**, the sensor data from the sensors **231-238**, the operational state data from the operational state detector **256**, and/or the abnormal event data from the abnormal event detector **254**, and select the (e.g., optimal) operational sequence to be performed by the well construction equipment based on such well construction plan **252**, sensor data, operational state data, and/or abnormal event data.

The operational sequence selector **258** may be operable to analyze or otherwise process the well construction plan **252** and discretize (e.g., break up or segment) the well construction plan **252** into a plurality of planned tasks or operational sequences that can be implemented (i.e., caused to be performed) by the central controller **192**. For example, the operational sequence selector **258** may be operable to analyze or otherwise process the well construction plan **252** and discretize each planned task (e.g., step) defined in the well construction plan **252** into one or more discrete operational sequences that can be received and implemented by the central controller **192**. A planned task may include, for example, drilling from depth A to depth B with the set of operation parameters, performing a survey, or performing a telemetry operation. Thus, the operational sequence selector **258** may be operable to select an operational sequence and an associated electrical power demand profile to be performed by the well construction equipment to perform a planned task defined in the well construction plan **252**. The control process **250** and/or the power manager **262** may then receive the selected operational sequence to be performed by the well construction equipment and, based on such selected operational sequence, output control data to cause the well construction equipment to perform the selected operational sequence and, thus, the corresponding planned task. The operational sequence selected and output by the operational sequence selector **258** based on the well construction plan **252** may be referred to hereinafter as a planned operational sequence.

The operational sequence selector **258** may also or instead be operable to analyze or otherwise process the detected abnormal event and select an operational sequence to be performed by the well construction equipment based on such abnormal event to stop or otherwise mitigate the detected abnormal event. The control process **250** and/or the power manager **262** may then receive the selected operational sequence to be performed by the well construction equipment and, based on such selected operational sequence, output control data to cause the well construction equipment to perform the selected operational sequence, thereby mitigating the abnormal downhole event. The control process **250** and/or the power manager **262** may cause the well construction equipment to perform the operational sequence selected based on the detected abnormal event while the planned operational sequence is still being performed. However, the control process **250** and/or the power manager **262** may instead output control data to cause the well construction equipment to stop performing the planned operational

21

sequence, before outputting the control data to cause the well construction equipment to perform the operational sequence selected based on the detected abnormal event. The operational sequence selected and output by the operational sequence selector **258** based on the detected abnormal event may be referred to hereinafter as a mitigating operational sequence.

The central controller **192** may further comprise a memory device operable to receive and store a database **260** (e.g., a library) of operational sequences that may be performed by the well construction equipment. Each stored operational sequence may comprise a plurality or series of physical or mechanical operations (e.g., actions, movements, etc.) that may be performed by one or more pieces of the well construction equipment and a corresponding electrical power demand profile associated with each plurality or series of physical or mechanical operations.

Some of the operational sequences (e.g., planned operational sequences) may be performed by corresponding pieces of the well construction equipment to perform a corresponding planned portion of the well construction operations (e.g., to drill a corresponding stage of the planned well). The database **260** may store operational sequences for performing each planned well construction task of the well construction plan **252**. The database **260** may store a plurality of alternate operational sequences associated with (i.e., for performing) a planned well construction task or a procedure (e.g., a portion of a well construction task comprising a plurality of mechanical operations) to be performed by the well construction equipment, such as when a status or certain condition of well construction operations changes. Thus, each well construction task or procedure may be associated with a plurality of different and/or alternate planned operational sequences for performing a planned well construction task or procedure. Accordingly, each planned operational sequence associated with a planned well construction task may comprise a different plurality of actions or movements to be performed by the well construction equipment to perform the planned well construction task or procedure.

Some of the operational sequences (e.g., mitigating operational sequences) may be performed by corresponding pieces of the well construction equipment to stop or otherwise mitigate a detected abnormal event. The database **260** may store a plurality of alternate operational sequences associated with (i.e., for performing) various types and/or levels of abnormal events that can take place during well construction operations. For each abnormal event, one or more operational sequences may be defined in association with corresponding priority and/or decision making steps, and saved in the database **260** and/or as part of the operational sequence selector **258**. The operational sequence selector **258** may automatically select one or more of the most responsive or optimal operational sequences based on parameters (e.g., type, severity, duration of time, etc.) of the abnormal event. Some abnormal events may be associated with a plurality of different and/or alternate planned operational sequences for performing a planned well construction task or procedure while stopping or otherwise mitigating the detected abnormal event and/or the effects of the detected abnormal event. Some abnormal events may be associated with a plurality of different and/or alternate planned operational sequences that are performed to stop or otherwise mitigate the detected abnormal event after a previously selected planned operational sequence is stopped. Thus, each mitigating operational sequence associated with a different abnormal event may comprise a different plurality

22

of actions or movements to be performed by the well construction equipment to stop or otherwise mitigate the detected abnormal event. Thus, when an abnormal event is detected, the control process **250** and/or the power manager **262** may stop performance of a previously selected planned operational sequence, the operational sequence selector **258** may select a mitigating operational sequence based on the detected abnormal event, and the control process **250** and/or the power manager **262** may output control data to cause the well construction equipment to perform the selected mitigating operational sequence thereby mitigating the abnormal downhole event without manual control of the well construction equipment by the rig personnel via the control workstation **197**.

The memory device storing the database **260** may be or form a portion of the central controller **192**. For example, the database **260** may be stored on a memory device (e.g., a memory chip) of the central controller **192** that is different from the memory device on which the executable program code instructions for the control process **250** and/or the operational sequence selector **258** are stored. The database **260** may also or instead be stored on the same memory device that stores the executable program code instructions for the control process **250**, the operational sequence selector **258**, and/or the power manager **262**. The database **260** may also or instead be stored on a memory device external from the central controller **192** communicatively connected with the central controller **192**. The database **260** may be or form a portion of the operational sequence selector **258** or the operational sequence selector **258** may have access to the planned and mitigating operational sequences stored in the database **260**. Therefore, the operational sequence selector **258** may be operable to select from the database **260** an operational sequence to be performed by the well construction equipment.

The control process **250** and/or the power manager **262** may be operable to receive a selected operational sequence from the sequence selector **258** and automatically operate the well construction equipment accordingly to implement the selected operational sequence. For example, if the selected operational sequence is to trip in a stand within a particular tripping speed, with the pump turned off, the control process **250** can ensure that the pump is turned off and that the drawworks is running at an intended speed, and the power manager **262** can ensure that the PS system **218** outputs sufficient electrical power to operate the drawworks and does so at optimum energy efficiency. If the selected operational sequence is to trip in a drill string from depth A to depth B, which may mandate the well construction system **100** to run multiple stands automatically, the control process can automatically manage and synchronize multiple pieces of well construction equipment, including, tripping, setting slips, breaking connections, picking up a new stand, making connections, releasing slips, and tripping in, without manual control of the well construction equipment by rig personnel via the control workstation **197**.

The present disclosure is further directed to a supervisory control system communicatively connectable with a rig control system of a fully operational well construction rig (i.e., well drilling or construction system) and operable to control selected portions of the well construction rig via the rig control system. The supervisory control system may be installed on or integrated with the well construction rig while the well construction rig is being constructed. The supervisory control system may instead be installed on or integrated with a previously constructed and fully operational well construction rig. The supervisory control system

23

may be configured to communicate with and control a rig control system, including a rig control system that utilizes a communication protocol that is different from the communication protocol utilized by the supervisory control system. Thus, the supervisory control system may be installed on or integrated with well construction rigs constructed by different manufacturers. The supervisory control system may be operable to automate selected operations of the well construction operations of the well construction rig and, thus, cause the selected operations to be performed without manual control of the well construction equipment by rig personnel (e.g., driller) via a rig control workstation. The supervisory control system may be operable to make decisions related to selection of actions or sequences of operations that are to be implemented during the well construction operations and/or the manner (e.g., speed, torque, power, etc.) in which such selected operations are to be implemented. Thus, the supervisory control system may operate as a virtual driller that can make well construction (e.g., drilling) decisions related to how a well is constructed by the well construction rig.

FIG. 3 shows a schematic view of an example supervisory control system 270 according to one or more aspects of the present disclosure. The supervisory control system 270 may be installable in association with a well construction system (such as the well construction system 100 shown in FIGS. 1 and 2) and operable to control selected portions of such well construction system via a rig control system 200 (such as the rig control system 200 shown in FIG. 2). The supervisory control system 270 may comprise one or more features and modes of operations of the central controller 192 described herein and shown in FIG. 2, including where indicated by the same reference numerals. Accordingly, the following description refers to FIGS. 1-3, collectively.

The supervisory control system 270 may be communicatively connectable with the rig control system 200, such as may permit the supervisory control system 270 to monitor and automatically control one or more components of the well construction equipment of the well construction system 100, including well construction equipment of one or more of subsystems 211-218. For example, the supervisory control system 270 may be communicatively connectable with the central controller 192 of the rig control system 200 to communicatively connect the supervisory control system 270 with the rig control system 200. The supervisory control system 270 may comprise a supervisory controller 272 communicatively connectable with the rig control system 200. The supervisory controller 272 may be communicatively connectable with the communication network 209 via a connection interface 274 to communicatively connect the supervisory controller 272 to the central controller 192. The supervisory controller 272 may be operable to communicate with the well construction equipment (e.g., actuators 241-248) of the subsystems 211-218 directly and/or via the central controller 192, such as may permit the supervisory controller 272 to monitor and automatically control the subsystems 211-218. The supervisory controller 272 may be implemented in a PLC, an IPC, a PC, a soft PLC, and/or other equipment controller or processing devices operable to store program code instructions, receive sensor data and/or control data, and cause operation of controllable equipment based on such program code instructions, sensor data, and/or control data. The supervisory controller 272 may be or comprise a backend server computer communicatively connected with the central controller 192. The supervisory controller 272 may be installed or otherwise located within the control center 190 or at another location of the well

24

construction system 100. Although the supervisory controller 272 is shown as a single device (i.e., a discrete hardware component), it is to be understood that the supervisory controller 272 may be or comprise a plurality of devices collectively comprising the structure and mode of operation described herein.

Communications between the control systems 200, 270 may be guided by principles aimed at ensuring personal safety of rig personnel at the well construction system 100 as well as safety of the well construction equipment and the well. Supervisory control system 270 and the communication interface 274 with the rig control system 200 are configured to be “non-critical” systems over the rig control system 200. Namely, if the supervisory control system 270 goes down, the well construction system 100 may still be operated (e.g., manually controlled) via the rig control system 200. Furthermore, the rig control system 200 has limited knowledge of (e.g., feedback from) the supervisory control system 270. For example, the rig control system 200 receives command data from the supervisory control system 270 that is similar to manual commands from the rig personnel (e.g., driller) using the control workstation 197. Thus, the rig control system 200 is aware of the presence of a “remote-control” supervisory control system 270 without knowing the context of the control commands the control system 200 receives.

The rig control system 200 is still responsible for ensuring safety of personnel and equipment, and can override the supervisory control system 270. Thus, safety at the well construction system 100 is bound by the existing protections of the rig control system 200. Furthermore, individual control commands from the supervisory control system 270 are “complete” and do not “require” a response to be sent to the supervisory control system 270 to be executed. The supervisory control system 270 has communication access and control over functions of the rig control system 200 utilized to perform current workflows of the supervisory control system 270. The supervisory control system 270 may not access arbitrary controls available on the different equipment unless explicitly permitted. The rig personnel have to grant explicit authorization from the control workstation 197 for remote control of the supervisory control system 270 to be activated. Furthermore, the supervisory control system 270 is not able to seize control of a piece of well construction equipment without explicit authorization from the rig personnel using the control workstation 197.

Prior to installation of the supervisory control system 270 on a well construction system 100, a listing of supervisory control system authority revoking conditions for revoking (e.g., stopping, ending) automatic control by the supervisory control system 270 has to be agreed upon between IT managers or operators of the supervisory control system 270 and the rig control system 200. For example, authorization can be automatically revoked, canceled, or ended if the rig personnel interact with the control workstation 197 for a piece of well construction equipment that has already been granted automated control authorization (e.g., pulling on a joystick to control the drawworks 118 will revoke control authority of the supervisory control system 270) according to the authorization listing. Furthermore, communication problems detected between the well construction equipment and the supervisory control system 270 can also cause the automated control authorization to be revoked.

The supervisory control system 270 may further comprise an HMI 276 usable by the rig personnel (e.g., the driller) to monitor and control the supervisory control system 270 to monitor and control the well construction equipment of the

25

well construction system **100**. The HMI **276** may be communicatively connected with the supervisory controller **272** and operable for entering or otherwise communicating control data to the supervisory controller **272** by the rig personnel for controlling the supervisory control system **270** and the well construction equipment of the well construction system **100**. The HMI **276** may be further operable for displaying or otherwise communicating sensor data and other information from the supervisory controller **272** to the rig personnel, thereby permitting the rig personnel to monitor the supervisory control system **270** and the well construction equipment of the well construction system **100**. For example, the HMI **276** may be operable to display to the rig personnel the current operational status of the well construction equipment. The HMI **276** may be or comprise a control workstation, a terminal, a computer, or another device comprising one or more input devices (e.g., a keyboard, a mouse, a joystick, a touchscreen, etc.) and one or more output devices (e.g., a video monitor, a touchscreen, a printer, audio speakers, etc.). The HMI **276** may be physically installable in association with the control workstation **197** of the well construction system **100**, such as may permit the rig personnel (e.g., the driller) using the control workstation **197** to also use the HMI **276**. Communication between the HMI **276** and the supervisory controller **272** may be via wired and/or wireless communication means. However, for clarity and ease of understanding, such communication means are not depicted, and a person having ordinary skill in the art will appreciate that such communication means are within the scope of the present disclosure.

The supervisory controller **272** may be operable to receive and store machine-readable and executable program code instructions on a memory device and then execute such program code instructions to run, operate, or perform one or more of a control process **250** (instead of or in addition to the central controller **192**), an abnormal event detector **254** (shown in FIG. 2), an operational state detector **256** (shown in FIG. 2), a sequence selector **258**, and a power manager **262** to monitor and control, as described herein, one or more of the well construction equipment of the well construction system **200**, including well construction equipment of one or more of subsystems **211-218**. The supervisory controller **272** may further comprise a memory device operable to receive and store one or more of a well construction plan **252** and a sequence database **260**, which may be accessed by one or more of the control process **250**, the abnormal event detector **254**, the operational state detector **256**, the sequence selector **258**, and the power manager **262** to facilitate the methods, processes, and operations described herein. Thus, the supervisory controller **272** may perform or facilitate performance of one or more of the methods, processes, and operations performed by the central controller **192** described in association with FIG. 2.

FIG. 4 is a schematic view of at least a portion of an example implementation of a PS system **300** of the well construction system **100** shown in FIGS. 1 and 2 communicatively connected via a communication network **209** with the central controller **192** shown in FIG. 2. The PS system **300** may comprise one or more features and modes or operation of the PS system **218** shown in FIG. 2. Accordingly, the following description refers to FIGS. 1, 2, and 4, collectively.

The PS system **300** may comprise a plurality of energy sources of electrical power electrically connected to an electrical power supply line **302** (e.g., 600 volt/60 Hertz main line or bus and other electrical networks) of the well construction system **100**, such as may permit the electrical

26

power sources to output electrical power to or via the line **302**. The electrical power sources may comprise one or more engine/electrical generator units **310**, one or more electrical energy storage units **312** (or systems), and an electrical power grid **314**. The PS system **300** may also comprise a source **316** of hydrogen gas connected with the generator units **310**. The central controller **192** may be communicatively connected with the electrical power sources **310**, **312**, **314** and the hydrogen source **316** via conductors **318** configured to communicate sensor data (e.g., output data, feedback data) to the central controller **192** to permit the central controller **192** to monitor operational status of the electrical power sources **310**, **312**, **314** and the hydrogen source **316**. The central controller **192** may be communicatively connected with the electrical power sources **310**, **312**, **314** via conductors **319** configured to communicate control data (e.g., output data, control commands) from the central controller **192** to the electrical power sources **310**, **312**, **314** to permit the central controller **192** to control operational parameters of the electrical power sources **310**, **312**, **314** and the hydrogen source **316**. The conductors **318**, **319** may be or comprise a portion of the communication network **209**. Wellsite equipment **304** of the well construction system **100**, such as the well construction equipment of one or more of the well construction subsystems **211-217**, may be electrically or otherwise operatively connected with the line **302** such as may permit the wellsite equipment **304** to receive electrical power to facilitate well construction operations performed by the wellsite equipment **304**.

The well construction system **100** may comprise, for example, two, three, four, five, six, or more generator units **310**. Each generator unit **310** may comprise a combustion engine (e.g., a diesel engine, a diesel/natural gas mixture (or other dual-fuel) engine, a gas turbine, a hydrogen engine, etc.) mechanically connected with and configured to rotate or otherwise actuate an electrical generator to output electrical power to the line **302**. Each generator unit **310** may further comprise a local control system comprising various electrical controllers and actuators (e.g., speed controller, voltage controller, electrical connectors, switches, circuit breakers, and/or relays) for controlling operational parameters of the generator unit **310**. The local control system also comprises a plurality of sensors for monitoring operational status of the generator units **310**. The generator units **310** may be skidded or otherwise mounted to a frame permitting transportation (e.g., via roadways) and installation (e.g., via cranes or lifts) at the wellsite **104**.

The scope of the present disclosure also includes implementations in which the power sources and/or storage units **312** include other types electrical power generation and/or storage devices. For example, one or more of the power sources may be or include an engine powered by non-diesel combustible fuel, electrical energy, solar energy, wind energy, regenerative power, power from flare gas combustion, thermal recapture, and/or other energy sources. Similarly, one or more of the storage units **312** may be or include one or a combination of batteries, hydrogen fuel cells, ultracapacitors (graphene), and/or other energy storage means.

Each generator unit **310** may be communicatively connected with the central controller **192**, such as may permit the power manager **262** to output control data to control operation of each generator unit **310**, including to control operating status (e.g., on/off status) of each generator unit **310** and/or to control the amount of electrical power that is output to the line **302** or otherwise made available to the wellsite equipment via the line **302**. The power manager **262**

may receive various sensor data (i.e., feedback data) from the generator unit **310**, analyze such sensor data, and output control data to the generator unit **310** to control operation of the generator unit **310** based on the received sensor data and other data. The sensor data output by each generator unit **310** to the power manager **262** may comprise data indicative of, for example, current operating status of the engine and/or the electrical generator, current fault status, current operating speed of the engine and/or the electrical generator, current throttle position of the engine, current engine load (e.g., load percentage with respect to maximum engine load), current electrical power generated, current engine power output, current electrical voltage generated, current electrical current generated, current fuel (e.g., diesel fuel or natural gas) consumption rate (e.g., flow rate) of the engine, and current temperature of the engine and/or the electrical generator. The control data output by the power manager **262** to each generator unit **310** may comprise data indicative of, for example, intended operating status of the engine and/or the electrical generator, intended operating speed of the engine and/or the electrical generator, intended throttle position of the engine, intended engine load, intended electrical power generated, intended engine power output, intended electrical voltage generated, intended electrical current generated, intended fuel consumption rate of the engine, and intended blackout limits.

One or more exhaust sensors **320** (e.g., sniffers) may be operatively connected with or along an exhaust port or the line **322** of each generator unit **310**. The exhaust sensors **320** may be operable to output sensor data (e.g., sensor signals or measurements) indicative of various quantitative and qualitative properties of the exhaust output by the engine of each generator unit **310**. The exhaust sensors **320** may be communicatively connected with the central controller **192**, such as may permit the power manager **262** to receive the sensor data (i.e., feedback data) from corresponding exhaust sensors **320** to monitor operational status of the engines, analyze such sensor data, and output control data to the generator units **310** to control operation of the generator units **310** and the hydrogen source **316** based on the received sensor data. The sensor data output by the exhaust sensors **320** to the power manager **262** may comprise data indicative of, for example, quantity of particulate material (PM), quantity of carbon monoxide (CO), quantity of carbon dioxide (CO₂), quantity of nitric oxide (NO), and quantity of nitrogen dioxide (NO₂) (collectively referred to hereinafter as "exhaust emissions").

The electrical power grid **314** may be or comprise a power generation or distribution station (i.e., an electrical utility station) located offsite or otherwise at a distance from the wellsite **104** and electrically connected with the line **302** via an electrical power line **324** (e.g., an electrical hi-line). An electrical power transformer **326** (e.g., a step-down transformer) may be electrically connected along the line **324** to step down voltage via the line **324**. An electrical connector **328** (e.g., an electrical switch and/or relay) may be electrically connected along the line **324**. The electrical connector **328** may be operable to connect the electrical power grid **314** to the line **302**. The electrical connector **328** may be communicatively connected with the central controller **192**, such as may permit the power manager **262** to output control data to control operation of the electrical connector **328**, including to control the electrical connector **328** to selectively connect the electrical power grid **314** to and disconnect the electrical power grid **314** from the line **302** and/or to control

the amount of electrical power that is transmitted to the line **302** or otherwise made available to the wellsite equipment via the line **302**.

A kilowatt/kilovolt-amperes reactive (kW/kVAR) transducer (or other sensor) **330** may be electrically connected to or along the line **324**. The transducer **330** may output sensor data indicative of various electrical properties (e.g., real and reactive electrical power) of the electrical power supplied by the electrical power grid **314**. The transducer **330** may be communicatively connected with the central controller **192**, thereby permitting the power manager **262** to receive and process the sensor data, and thus monitor or measure the electrical properties of the electrical power supplied by the electrical power grid **314** and available to the wellsite equipment **304** based on the received sensor data and other data. The power manager **262** may then output control data to the electrical connector **328** to control operation of the electrical connector **328** to selectively connect the electrical power grid **314** to the line **302**. The power manager **262** may also output control data to the electrical connector **328** to control the amount of electrical power that is transmitted to the line **302** or otherwise made available to the wellsite equipment via the line **302**. Although the transducer **330** is shown electrically connected with the line **324** before the electrical power is transformed to an intended voltage and frequency (and other characteristics) for use by the wellsite equipment **304** via the line **302**, the transducer **330** may be electrically connected with the line **324** downstream from the transformer **326**, such as may permit the power manager **262** to monitor available electrical power after the electrical power is transformed for use by the wellsite equipment **304**. Although the transformer **326**, the electrical connectors **328**, and the transducer **330** are shown as separate elements, the transformer **226**, the electrical connectors **328**, and/or the transducer **330** may be implemented as part of the same device or unit.

The electrical energy storage unit **312** may be operable to selectively receive and store electrical power generated by the generator units **310** and/or supplied by the electrical power grid **314**, and then selectively output the stored electrical power to the various electrical actuators of the wellsite equipment **304**. The storage unit **312** may comprise a plurality of electrical storage devices (e.g., batteries, capacitors) connected in series and in parallel, and collectively operable to store sufficient amount of electrical power to operate predetermined one or more of the wellsite equipment **304** for a predetermined period of time. The storage unit **312** may be operable to store, for example, between about 500 kilowatt-hours and 1.00 megawatt-hour of electrical power. The storage unit **312** may be operable to output the stored electrical energy at maximum rates ranging, for example, between about 1.00 megawatt and about 1.50 megawatts. The storage unit **312** may further comprise a bi-directional inverter operable to change the alternating current (AC) supplied by the generator units **310** and the electrical power grid **314** to direct current (DC) power for storage by the electrical storage devices, and change the DC power stored by the electrical storage devices to AC power for use by the wellsite equipment **304**. The storage unit **312** may further comprise a control system comprising various electrical controllers and actuators (e.g., electrical connectors, switches, circuit breakers, and/or relays) for controlling operational parameters of the storage unit **312** and a plurality of sensors for monitoring operational status of the storage unit **312**. The storage unit **312** may be skidded or otherwise

29

mounted to a frame permitting transportation (e.g., via roadways) and installation (e.g., via cranes or lifts) at the wellsite **104**.

The electrical energy storage unit **312** may be communicatively connected with the central controller **192**, such as may permit the power manager **262** to output control data to control operation of the storage unit **312**, including to control operating status (e.g., on/off status, charge/discharge, rate of charge/discharge) of each storage unit **312** and/or to control the amount of electrical power that is output to the line **302** or otherwise made available to the wellsite equipment via the line **302**. The power manager **262** may receive various sensor data (i.e., feedback data) from the sensors of the storage unit **312**, analyze such sensor data, and output control data to the storage unit **312** to control operation of the storage unit **312** based on the received sensor data and other data. The sensor data output by the storage unit **312** to the power manager **262** may comprise data indicative of, for example, current operating status, current fault status, current battery health status, current status of electrical connection with the line **302**, current state of battery charge (e.g., current battery charge percentage with respect to maximum battery capacity), current battery efficiency, current power output (e.g., real and reactive power) to the line **302**, current AC and DC electrical voltage, current AC and DC electrical current, current AC electrical frequency, quantity of charge cycles, current peak load shaving, current load applied to the engine of the generator units **310**, current temperature of the battery and/or the inverter. The control data output by the power manager **262** to the storage unit **312** may comprise data indicative of, for example, intended operating status, intended status of electrical connection with the line **302**, intended battery charge, intended battery efficiency, intended power output to the line **302**, intended AC and DC electrical voltage, intended AC and DC electrical current, intended AC electrical frequency, intended quantity of charge cycles, intended peak load shaving, and intended load to be applied to the engine of the generator units **310**.

The storage unit **312** may be selectively electrically connected to the generator units **310** and/or the electrical power grid via the line **302**, such as may permit the storage unit **312** to be selectively operated by the power manager **262** to receive and store the electrical power output to the line **302** by the generator units **310** and/or by the electrical power grid **314**. The storage unit **312** may be electrically connected to the generator units **310** in parallel, such that the storage unit **312** operates or appears as a load to the generator units **310** when the storage unit **312** is storing electrical power output by the generator units **310**. Utilization of the storage unit **312** as a load facilitates a more efficient operation of the engines (e.g., low engine load results in higher fuel consumption and emissions) of the generator units **310**. Thus, if one or more of the generator units **310** operate at low efficiency, the storage unit **312** can be operated to a "charge" state to store the electrical energy output by the generator units **310**, thereby causing a higher load demand on the generator units **310** that will result in lower fuel consumption and emissions by the engines of the generator units **310**. The storage unit **312** may also be selectively operated by the power manager **262** to output the stored electrical energy at a selected rate to the wellsite equipment **304** via the line **302** to provide electrical power to operate the wellsite equipment **304** as described herein. The power manager **262** can also receive data from the well construction plan **252** to ensure that the storage unit **312** is fully charged to facilitate optimal distribution and utilization

30

of electrical energy output by the energy storage unit **312**, the generator units **310**, and the electrical power grid **314**.

The hydrogen source **316** may be operable to store or generate hydrogen gas and selectively discharge or output the hydrogen gas into an air intake of the engine of each of the generator units **310** via a corresponding fluid conduit **317**. The hydrogen source **316** may be or comprise a container (e.g., a tank) of a hydrogen and oxygen gas mixture, which can be discharged into the engines. The hydrogen source **316** may be or comprise an electrolysis hydrogen generator unit operable to produce hydrogen gas via electrolysis. The electrolysis hydrogen generator unit may comprise a container of distilled water and a plurality of electrodes submerge therein. Electrical current may be applied to the submerged electrodes, causing the water to be separated into hydrogen and oxygen gases. The released hydrogen (and oxygen) may be captured and selectively discharged into the engines. The electrolysis hydrogen generator unit may operate in an "on demand" mode of operation, during which the hydrogen (and oxygen) mixture is produced via the electrolysis process and injected at the rate it is produced while the generator units **310** are running. During the on demand mode, the electrolysis process stops when the generator units **310** are turned off. The released hydrogen mixture may also be stored within a container to permit regulated injection of the hydrogen mixture into the engines. The flow rate of the hydrogen into the engines may be regulated via remotely operated fluid flow control valves communicatively connected with the central controller. The total amount of hydrogen injected and times during which injection occurs may be determined based on sensor data output by the exhaust sensors **320** and/or based on control data output by a local controller (e.g., an onboard engine controller) of each generator unit **310**. By combining the dual feedback sources, the power manager **262** can optimize the performance of the generator units **310** based on total output power performance and/or based on exhaust emissions discharged by the generator units **310** measured by the exhaust sensors **320**.

The hydrogen gas can function as a fuel enhancer improving combustion of air and fuel (e.g. diesel fuel) mixture within combustion cylinders of the engine of each generator unit **310**. For example, when the hydrogen gas is added and mixed with the air/fuel mixture, the hydrogen gas disperses more efficiently within the cylinder and, after the diesel ignites, the hydrogen burns at a faster rate, thereby improving burning of the fuel (e.g., completeness of burning or percentage of fuel in the combustion cylinder that is burned). Such improved burning of the fuel can increase the amount of energy released during combustion, resulting in higher torque output and higher efficiency of the engine. The improved burning of the fuel can result in lower emissions of the exhaust emissions produced during well construction operations. The improved burning of the fuel can result in a lower consumption rate of the fuel, because the intended power output by the engine can be achieved with smaller volumes or flow rate of fuel. Conversely, the improved burning of the fuel, air, and hydrogen mixture can result in higher power output by the engine than when burning the fuel and air mixture alone. The combination of the generator units **310** and the hydrogen source **316** can collectively improve efficiency of the PS system **300**, such that the well construction system **100** may be capable of performing the well construction operations using fewer (e.g., one, two, or three less) generator units **310**. Utilization of the hydrogen gas also reduces the dependency on fossil fuels (e.g., gas from a compressed storage tank or local processing plant

31

required for modern diesel/gas blend engines) and can be available at all times, whereas power from the electrical power grid 314 or alternative fuels may not always be readily available.

The PS system 300 may further comprise a kW/kVAR transducer 332 or another sensor electrically connected to or along the line 302. The transducer 332 or other sensors may output sensor data indicative of various electrical properties (e.g., voltage, current, real and reactive electrical power, etc.) of the electrical power demand by the wellsite equipment 304 of the well construction system 100 via the line 302. The transducer 332 may be communicatively connected with the central controller 192, thereby permitting the power manager 262 to receive and process the sensor data and, thus, monitor or measure the electrical properties of the electrical power supplied by the electrical power grid 314 and available to the wellsite equipment 304, based on the received sensor data and other data. The power manager 262 may then output control data to various portions of the PS system 300 (e.g., the generator units 310 and the storage unit 312) to control the PS system 300 based on the total electrical power demand ("electrical power demand level"), including to control generation and distribution of electrical power ("electrical power output level") to the line 302 by the electrical power sources 310, 312, 314. The power manager 262 may control generation and distribution of electrical power to the line 302 by the electrical power sources 310, 312, 314 based on the most efficient sources of power available, taking into consideration directives to reduce total fuel consumption and emissions into the local environment.

FIG. 5 is a schematic view of at least a portion of an example implementation of the PS system 300, shown in FIG. 4, communicatively connected via the communication network 209 and/or the communication interface 274 with the central controller 192 of the rig control system 200 and the supervisory controller 272 of the supervisory system 270, both shown in FIG. 3. The following description refers to FIGS. 1 and 3-5, collectively.

The supervisory control system 270 may be communicatively connectable with the rig control system 200, such as may permit the supervisory control system 270 to monitor and automatically control one or more components of the well construction equipment of the well construction system 100, including the wellsite equipment 304 (e.g., well construction equipment of one or more of subsystems 211-218). The supervisory control system 270 may comprise the supervisory controller 272 communicatively connectable with the rig control system 200. The supervisory controller 272 may be communicatively connectable with the communication network 209 via the connection interface 274 to communicatively connect the supervisory controller 272 to the central controller 192. The supervisory controller 272 may be operable to receive and store machine-readable and executable program code instructions on a memory device and then execute such program code instructions to run, operate, or perform one or more of a control process 250 (instead of or in addition to the central controller 192), an abnormal event detector 254 (shown in FIG. 2), an operational state detector 256 (shown in FIG. 2), a sequence selector 258, and a power manager 262 to monitor and control, as described herein, one or more of the wellsite equipment 304. The supervisory controller 272 may further comprise a memory device operable to receive and store one or more of a well construction plan 252 and a sequence database 260, which may be accessed by one or more of the control process 250, the abnormal event detector 254, the operational state detector 256, the sequence selector 258,

32

and the power manager 262 to facilitate the methods, processes, and operations described herein. Thus, the supervisory controller 272 may perform or facilitate performance of one or more of the methods, processes, and operations performed by the central controller 192 described in association with FIG. 2.

The present disclosure is further directed to systems and methods for monitoring and controlling collective operations of the electrical power sources at a wellsite to optimize collective operation of such electrical power sources to optimize well construction and/or other operations at a wellsite. As described above, efficiency of generator units increases while load on its engine increases. For example, fuel efficiency of generator units (e.g., diesel fuel generating units) may be optimal at engine loads ranging between, for example, about 50% and about 100%. However, during well construction operations, generator units collectively output electrical power to match electrical power demands of the well construction equipment, regardless of efficiency. Thus, during stages of well construction operations requiring relatively low levels of electrical power, the generator units collectively operate at low efficiencies. Efficiency of the generator units is also relatively low during generator warm-up periods, which may take several minutes. Furthermore, while operating at a low efficiency rate or before a proper warm-up, the generator units discharge exhaust emissions and unburnt fuel at higher rates. However, during stages of well construction operations utilizing relatively high levels of electrical power, one or more additional generator units may be turned on to provide additional electrical power without permitting the additional generator units to properly warm up.

During well construction operations, electrical power demand changes frequently and significantly during different stages of the well construction operations. For example, electrical power demand may be relatively high during actual drilling, when the top drive 116 rotates the drill string 120 and the mud pumps 144 are circulating drilling fluid into the wellbore 102 via the drill string 120. Such electrical power demand may increase as the total or true vertical depth of the wellbore 102 increases. Electrical power demand may be relatively low during make-up operations, when the iron roughneck 165 is operating and the top drive 116 is not rotating the drill string 120 and the mud pumps 144 are not circulating the drilling fluid. The electrical power demand may suddenly increase to relatively high levels during tripping operations, when the drawworks 118 lifts the drill string 120 upward. Electrical power demand may be relatively low during break out operations, when the iron roughneck 165 is operating to disconnect each subsequent tubular joint and the drawworks 118 is not lifting the drill string 120 upward. Electrical power demand may progressively decrease during tripping operations while the total length of the drill string 120 decreases after each tubular joint is disconnected from the drill string 120. Electrical power demand changes significantly during transitions between actual drilling operations and make-up operations, and during transitions between tripping operations and break out operations. For example, during a spudding stage of the well construction operations, electrical power demand may range between about 0.4-0.6 megawatts. During connection (e.g., make-up or break out) operations, electrical power demand may range between about 0.3-0.7 megawatts. During tripping operations, electrical power demand may range between about 0.3-1.5 megawatts. During actual drilling operations, electrical power demand may range between about 2.0-3.0 megawatts.

33

Accordingly, one or more aspects of the present disclosure are directed to systems and methods for monitoring and controlling collective operations of the electrical power sources **310**, **312**, **314** of the PS system **300** at the wellsite **104** to optimize collective operation of such electrical power sources **310**, **312**, **314** to optimize well construction and/or other operations at the wellsite **104**. Operations of the PS system **300** may be managed (i.e., controlled) by the power manager **262** (and the control process **250**) of the central controller **192** shown in FIGS. **2** and **4** or by the power manager **262** (and the control process **250**) of the supervisory controller **272** shown in FIGS. **3** and **5**, so as to provide electric power to the wellsite equipment **304** to perform the well construction and other wellsite operations, while increasing efficiency of the PS system **300** and reducing the use of nonrenewable energy sources (e.g., diesel fuel, natural gas, and other fossil fuels), exhaust emissions, and operating and maintenance costs. The following paragraphs describe several examples of monitoring and controlling of the PS system **300** and the wellsite equipment **304** by the power manager **262** (and the control process **250**) according to one or more aspects of the present disclosure. The power manager **262** may be operable to monitor and control collective operations of the electrical power sources **310**, **312**, **314** and the hydrogen source **316** to optimize collective operation of the electrical power sources **310**, **312**, **314** and the hydrogen source **316** and to reduce exhaust emissions, based on measured load demand caused by the wellsite equipment **304**, based on electrical power that is available from the electrical power sources **310**, **312**, **314**, and/or based on the well construction plan **252** comprising information indicative of upcoming operations.

The power manager **262** may be operable to monitor and control operations (e.g., start/stop and engine load percentage) of the generator units **310** based on measured load demand by the wellsite equipment **304** and electrical power that is available from the electrical power sources **310**, **312**, **314**. For example, during times (e.g., stages or periods) of lower peak electrical power demand (e.g., below about 1.0 megawatt) during which the well construction operations utilize relatively low levels of electrical power, the power manager **262** may turn off one or more of the generator units **310**, thereby causing the remaining generator units **310** to meet the electrical power demand and, thus, operate at higher efficiencies.

During times of lower average electrical power demand by the wellsite equipment **304**, the power manager **262** may also or instead maintain each generator unit **310** as operational or turn off fewer generator units **310** while simultaneously establishing an electrical connection between one or more of the operating generator units **310** and the storage unit **312** to charge the storage unit **312** while the generator units **310** continue to provide electrical power to the wellsite equipment **304**. The charging of the storage unit **312** increases the load on each operating generator unit **310**, thereby causing each operating generator unit **310** to operate at a high efficiency. Operating each generator unit **310** at higher efficiency reduces the amount of fuel consumed by each generator unit **310** per unit of electrical power produced. If the storage unit **312** becomes charged to a predetermined level (e.g., between about 65% and about 100%) before the time of lower average electrical power demand by the wellsite equipment **304** is over, then the power manager **262** may turn off one or more of the generator units **310**, such as may permit the operating generator units **310** to continue to operate at high efficiency. However, if the storage unit **312** becomes charged to a predetermined level

34

while the average electrical power demand by the wellsite equipment **304** is relatively low (e.g., below about 400 kilowatts), then the power manager **262** may turn off each of the generator units **310** and cause the storage unit **312** to supply electrical power to the wellsite equipment **304**. For example, during drill string tripping operations, the average electrical power demand may be about 460 kilowatts and the peak intermittent electrical power demand may be about 1.5 megawatts. During such drill string tripping operations, the power manager **262** may operate the storage unit **312** and just one generator unit **310** capable of generating about 1.0 megawatt to collectively supply electrical power to the wellsite equipment **304** (e.g., the drawworks **118**) to facilitate the drill string tripping operations. That is, the power manager **262** may cause the generator unit **310** and the storage unit **312** to collectively supply electrical power to the wellsite equipment **304** when the drill string **120** is being lifted. However, during break out operations, the power manager **262** may cause some of the electrical power from the generator unit **310** to supply electrical power to other wellsite equipment **304** (e.g., the iron roughneck **165** and other auxiliary devices) and some of the electrical power to be stored by the storage unit **312**, thereby retaining a high load on the generator unit **310** while continually charging and discharging the storage unit **312**. The power manager **262** may turn on one or more of the generator units **310** when the storage unit **312** becomes discharged or when the average electrical power demand by the wellsite equipment **304** increases.

The power manager **262** may also or instead be operable to monitor and control operations of the generator units **310** based on the well construction plan **252** uploaded or saved to the central controller **192** or the supervisory controller **272**. As described above, the well construction plan **252** may comprise a planned drilling profile and other information indicative of upcoming (i.e., near future) operations (e.g., events) to be performed by the wellsite equipment **304**. The well construction plan **252** may also comprise a planned electrical power demand profile indicative of electrical power demand levels for performing or otherwise associated with each planned stage, portion, sequence, task, and/or operation of the well construction operations. The drilling plan **252** may also comprise information indicative of electrical power output (or supply) capabilities of each power source of the PS system **300**. The power manager **262** may instead be operable to monitor and control operations of the generator units **310** based on an operational sequence selected from the sequence database **260** by the sequence selector **258** based on a detected abnormal event or operational state of the well construction system **100**.

For example, the power manager **262** may be operable to turn on or turn off one or more of the generator units **310** and/or charge the storage unit **312** based on information indicative of upcoming operations contained in the drilling plan **252**. During times of lower average electrical power demand, the power manager **262** may cause one or more of the generator units **310** to output electrical power and cause the storage unit **312** to receive and store the electrical power. The charging of the storage unit **312** increases the load on the operating generator units **310**, thereby causing the operating generator units **310** to operate at higher efficiency. Such operations of the generator units **310** and the storage unit **312** may be caused by the power manager **262** based on the drilling plan **252**. For example, when the power manager **262** determines that a time (e.g., a stage or period) of lower power demand (e.g., average or intermittent) is coming up in the near future, then the power manager **262** may turn off a

35

generator unit 310 or increase load on the generator unit 310 via the storage unit 312 at a substantially exact time at which the time of lower power demand starts, because such time is indicated in the drilling plan 252. Conversely, when the power manager 262 determines that a period of higher power demand (e.g., average or intermittent) is coming up in the near future, then the power manager 262 may turn on a generator unit 310 a predetermined amount of time (e.g., a few minutes) before the period of higher power demand starts, thus permitting that generator unit 310 to properly warm-up. The starting time of the period of higher power demand is known because such time is indicated in the drilling plan 252.

Furthermore, when the power manager 262 determines that a period of higher power demand (e.g., average or intermittent) is coming up in the near future, then the power manager 262 may cause the storage unit 312 to stop charging and output electrical power to the line 302 at a substantially exact time the period of higher power demand starts. Also, when the power manager 262 determines that a time period of intermittent higher power demand, but relatively low average power demand (e.g., the drill string tripping operations), is coming up in the near future, the power manager 262 may cause the storage unit 312 to store electrical power to meet such electrical power demand. For example, the power manager 262 may cause the storage unit 312 to increase the electrical load of the currently operating generator units 310 or the power manager may turn on an additional generator unit 310, whereby electrical power generated in excess of current electrical power demand can be stored by the storage unit 312 for use during the time period of intermittent high power demand. When the high power demand period is over, the power manager 262 may operate or utilize the energy storage unit 312 as a load to help maintain a more steady-state power load demand on the generator units 310. The power manager 262 may be further operable to optimize electrical power limit process (i.e., anti-blackout process) and/or provide advance warning for or otherwise determine when electrical load demand will exceed electrical power that is available from the electrical power sources 310, 312, 314, based on the drilling plan 252.

The power manager 262 may also or instead cause the storage unit 312 output more electrical power to the line 302 when the generator units 310 that are about to experience and/or are experiencing a high transient load (i.e., heavy block load or unload) based on the drilling plan 252. A high transient load can cause the engine of the generator unit 310 to significantly increase power output to accelerate the electrical generator of the generator unit 310 to ramp up electrical power output, such as based on sensor data from the transducer 332. During such high transient load, fuel is injected into the engine and burned at relatively high rates, resulting in relatively high output rates of exhaust emissions and unburnt fuel. During such high transient load, the engine and various other mechanical components (e.g., gears, shafts, belts) of a generator unit 310 experience high rates of wear caused by high levels and/or sudden changes in torque, backlash, and impacts experienced during high rates of acceleration of the engine. High rates of engine acceleration can also result in overshoot of engine speed and electrical power output, requiring the engine to slow down to a steady-state speed associated with the intended electrical power output, which causes further engine wear and efficiency. Likewise, during high transient unloading of the generator unit 310, the engine power output is suddenly decreased (e.g., by reducing fuel flow) to decelerate the engine, thereby permitting the speed of the generator unit to

36

decrease. However, when the electrical power output of the generator unit 310 reaches its intended level, the engine again accelerates at a high rate to maintain a steady-state speed and the associated electrical power output. Such repetitive heavy loading and unloading of the generator units 310 causes high rates of mechanical wear to the generator units 310.

Therefore, during a high transient load, the power manager 262 may cause the storage unit 312 to output more electrical power to the line 302, such that the generator units 310 experience a gradual increase in load (i.e., a soft load). The power manager 262 may cause the storage unit 312 to output more electrical power to the line 302 before or substantially at the same time as the generator units 310 that are experiencing the high transient load, based on the drilling plan 252. Outputting more electrical power into the line 302 by the storage unit 312 reduces the rate of load increase (i.e., soft loading) to the generator units 310, causing the generator units 310 to ramp up output of electrical power slowly, thereby burning less fuel and reducing output rates of exhaust emissions and unburnt fuel. Soft loading the generator units 310 prevents or inhibits high acceleration rates and overshooting the intended speed and electrical power production of the generator units 310, thereby reducing rates of mechanical wear of the generator units 310.

The power manager 262 may be operable to monitor and control operations of the generator units 310 based further on sensor data output by the exhaust sensors 320 indicative of properties of the exhaust emissions output by the engine of each generator unit 310. For example, if the power manager 262 determines that higher quantities or proportions of particulate material and/or gases are present in the engine exhaust, the power manager 262 may turn off the generator unit 310 or increase load on the generator unit 310 via the storage unit 312.

The power manager 262 may be operable to monitor operations of the generator units 310 and control (e.g., adjust) operation of the hydrogen source 316 to optimize operations of the generator units 310 by selectively injecting hydrogen into the engines of the generator units 310. The benefits of introduction of hydrogen into the engines is weighted against the effects of hydrogen embrittlement, which is a loss of ductility and reduction of load bearing capability of metal due to the absorption of hydrogen atoms or molecules by the metal. Therefore, the power manager 262 may cause the hydrogen source 316 to inject hydrogen into the engines of the generator units 310 on a limited basis, such as when hydrogen substantially improves efficiency and/or reduces exhaust emissions.

The power manager 262 may monitor power output by the engines of the generator units 310 and change the flow rate of hydrogen into the engines based on the measured power output and/or fuel efficiency. The power manager 262 may maintain the flow rate of hydrogen at a level resulting in the highest or otherwise optimal power output (e.g., when more engine torque is needed) and/or at a level resulting in the highest or otherwise optimal fuel efficiency (e.g., when steady-state electrical power output is attained). The power manager 262 may also or instead cause the hydrogen source 316 to inject hydrogen into the engine of one or more of the generator units 310 that are about to experience a high transient load based on information in the well construction plan 252 indicative of upcoming operations. Injecting hydrogen into the engine that is experiencing a high transient load improves burning of the fuel and/or reduces the

37

flow rate of fuel into the engine, and thus reduces output rates of exhaust emissions and unburnt fuel.

The power manager 262 may be operable to monitor and control operation of the hydrogen source 316 based further on sensor data output by the exhaust sensors 320. For example, the power manager 262 may monitor levels of exhaust emissions within the exhaust of the engines and change the flow rate of hydrogen into the engines based on the measured levels of exhaust emissions. When the power manager 262 determines that higher quantities or proportions of exhaust emissions are present in the engine exhaust, the power manager 262 may increase the flow rate of hydrogen into the engines to enhance combustion and, thus, reduce output of the exhaust emissions. The power manager 262 may maintain the flow rate of hydrogen at a level resulting in minimal output of the exhaust emissions.

The power manager 262 may be further operable to output control data to the electrical connector 328 to cause the electrical connector 328 to electrically connect the electrical power grid 314 to the line 302 to supply electrical power to the wellsite equipment 304 and/or to supply electrical power to the storage unit 312 to be stored for later use. The power manager 262 may determine whether to direct the electrical power from the electrical power grid 314 to the line 302 for use by the wellsite equipment 304 and/or for storage by the storage unit 312 based on current cost (i.e., price) of the electrical power supplied from the electrical power grid 314. Thus, when the cost of electrical power from the electrical power grid 314 is less than the cost of operating the generator units 310 (e.g., fuel and maintenance costs) and the hydrogen source 316, then the power manager 262 may direct the electrical power from the electrical power grid 314 to the line 302 for use by the wellsite equipment 304. The power manager 262 may also cause the storage unit 312 to receive electrical power from the electrical power grid 314 via the line 302 and store the electrical power for later use. However, when the cost of electrical power from the electrical power grid 314 is higher than the cost of operating the generator units 310 and the hydrogen source 316, such as during peak demand hours for the electrical power grid 314, then the power manager 262 may disconnect the electrical power grid 314 from the line 302 and operate the generator units 310 and/or the storage unit 312 as the sources of electrical power.

The power manager 262 may be further operable to direct the electrical power from the electrical power grid 314 to the line 302 for use by the wellsite equipment 304 when the generator units 310 and the storage unit 312 are not collectively operable to supply sufficient electrical power to the wellsite equipment 304 to perform the well construction operations, regardless of cost of electrical power from the electrical power grid 314. Such scenario may be caused by an unforeseen or otherwise unplanned event, such as an unforeseen drilling event requiring additional flow rate of drilling fluid or fast withdraw of the drill string 120 from the wellbore 102. Such scenario may also or instead be caused by an unforeseen breakdown in one or more of the generator units 310 and/or the storage unit 312, requiring such piece of equipment to be taken offline for maintenance.

The power manager 262 may also or instead determine whether to direct electrical power from the electrical power grid 314 to power the wellsite equipment 304 and/or to the storage unit 312 for storage based on the current amount of exhaust emissions discharged by the engines of the generator units 310. Thus, when the generator units 310 are producing high quantities of exhaust emissions, then the power manager 262 may direct the electrical power from the

38

electrical power grid 314 to the line 302 for use by the wellsite equipment 304 and/or for storage by the storage unit 312.

The power manager 262 may be further operable to change, adjust, or otherwise control operation of the wellsite equipment 304 when electrical power demand of the wellsite equipment 304 exceeds available power from the electrical power sources 310, 312, 314. Such operation, which may be referred to as an anti-blackout protection, is configured to prevent overload of the line 302 or other electric circuitry of the well construction system 100. Such scenario may happen, for example, when sufficient electrical power is not available from the electrical power grid 314 and an unplanned event takes place at the wellsite. An unplanned event may include, for example, an unforeseen drilling event requiring additional flow rate of drilling fluid or fast withdraw of the drill string 120 from the wellbore 102. An unplanned event may also include an unforeseen breakdown in one or more of the generator units 310, the storage unit 312, and/or the electrical power grid 314, requiring such piece of equipment to be taken offline for maintenance. In response to such electrical power demand, the power manager 262 may slow down or otherwise adjust operations of selected pieces of the wellsite equipment 304, such as the drawworks 118, the top drive 116, the pumps 144, and various pipe handling equipment collectively operable to move tubulars during the well construction operations. The power manager 262 may also or instead turn off predetermined operations of the well construction system 100, such as wellsite equipment 304 not essential to performing the well construction operations. The power manager 262 may control operations of the wellsite equipment 304 directly or via the control process 250.

The storage unit 312 may also be used temporarily to provide electrical energy to the wellsite equipment 304 when the other sources 310, 314 of electrical power are not operational (e.g., not yet online), fail, or are otherwise not available. For example, the storage unit 312 can facilitate a faster move of the well construction system 100 to another wellsite 104 or another well at the wellsite 104 by operating the storage unit 312 as the primary source of electrical power at the new wellsite 104 or well, while the generator units 310 and/or connection with the electrical power grid 314 are still in the process of being electrically connected or transported to the new location. Moving the well construction system 100 includes draining fuel tanks of the generator units 310 before the fuel tanks can be transported. The fuel tanks are then refilled at the new location. Such steps slow down the process of moving the generator units 312 between locations and getting the generator units 312 online at the new location. Thus, the power manager 262 may cause the storage device 312 to be fully charged before the well construction system 100 is taken offline, disassembled, and moved to the new location. The power manager 262 may be aware of an impending move of the well construction system 100 based on the well construction plan 252, which may contain the date and/or time of the impending move. To implement the move, the storage unit 312 may be moved first and electrically connected to the line 302 (i.e., well construction system power grid) before the generator units 310 and the electrical power grid 314 provide electrical power. The storage unit 312 may permit basic functions of the well construction system 100 to be started before the generator units 310 are installed at the new location and the electrical power grid 314 is electrically connected to the line 302. Such method may facilitate a faster rig up/rig down times.

FIG. 6 is a schematic view of at least a portion of an example implementation of a processing device **400** (or system) according to one or more aspects of the present disclosure. The processing device **400** may be or form at least a portion of one or more equipment controllers and/or other electronic devices shown in one or more of the FIGS. 1-5. Accordingly, the following description refers to FIGS. 1-6, collectively.

The processing device **400** may be or comprise, for example, one or more processors, controllers, special-purpose computing devices, PCs (e.g., desktop, laptop, and/or tablet computers), personal digital assistants, smartphones, IPCs, PLCs, servers, internet appliances, and/or other types of computing devices. The processing device **400** may be or form at least a portion of the rig control system **200**, including the central controller **192**, the supervisory controller **272**, the local controllers **221-228**, and the control workstation **197**. Although it is possible that the entirety of the processing device **400** is implemented within one device, it is also contemplated that one or more components or functions of the processing device **400** may be implemented across multiple devices, some or an entirety of which may be at the wellsite and/or remote from the wellsite.

The processing device **400** may comprise a processor **412**, such as a general-purpose programmable processor. The processor **412** may comprise a local memory **414**, and may execute machine-readable and executable program code instructions **432** (i.e., computer program code) present in the local memory **414** and/or another memory device. The processor **412** may be, comprise, or be implemented by one or more processors of various types suitable to the local application environment, and may include one or more of general-purpose computers, special-purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as non-limiting examples. Examples of the processor **412** include one or more INTEL microprocessors, microcontrollers from the ARM and/or PICO families of microcontrollers, embedded soft/hard processors in one or more FPGAs.

The processor **412** may execute, among other things, the program code instructions **432** and/or other instructions and/or programs to implement the example methods and/or operations described herein. For example, the program code instructions **432**, when executed by the processor **412** of the processing device **400**, may cause the processor **412** to receive and process (e.g., compare) sensor data (e.g., sensor measurements). The program code instructions **432**, when executed by the processor **412** of the processing device **400**, may also or instead output control data (i.e., control commands) to cause one or more portions or pieces of well construction equipment of a well construction system to perform the example methods and/or operations described herein.

The processor **412** may be in communication with a main memory **416**, such as may include a volatile memory **418** and a non-volatile memory **420**, perhaps via a bus **422** and/or other communication means. The volatile memory **418** may be, comprise, or be implemented by random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), RAMBUS DRAM (RDRAM), and/or other types of RAM devices. The non-volatile memory **420** may be, comprise, or be implemented by read-only memory, flash memory, and/or other types of memory devices. One or more memory controllers

(not shown) may control access to the volatile memory **418** and/or non-volatile memory **420**.

The processing device **400** may also comprise an interface circuit **424**, which is in communication with the processor **412**, such as via the bus **422**. The interface circuit **424** may be, comprise, or be implemented by various types of standard interfaces, such as an Ethernet interface, a universal serial bus (USB), a third generation input/output (3GIO) interface, a wireless interface, a cellular interface, and/or a satellite interface, among others. The interface circuit **424** may comprise a graphics driver card. The interface circuit **424** may comprise a communication device, such as a modem or network interface card to facilitate exchange of data with external computing devices via a network (e.g., Ethernet connection, digital subscriber line (DSL), telephone line, coaxial cable, cellular telephone system, satellite, etc.).

The processing device **400** may be in communication with various sensors, video cameras, actuators, processing devices, equipment controllers, and other devices of the well construction system via the interface circuit **424**. The interface circuit **424** can facilitate communications between the processing device **400** and one or more devices by utilizing one or more communication protocols, such as an Ethernet-based network protocol (such as ProfiNET, OPC, OPC/UA, Modbus TCP/IP, EtherCAT, UDP multicast, Siemens S7 communication, or the like), a proprietary communication protocol, and/or another communication protocol.

One or more input devices **426** may also be connected to the interface circuit **424**. The input devices **426** may permit rig personnel to enter the program code instructions **432**, which may be or comprise control data, operational parameters, operational set-points, a well construction plan, and/or a database of operational sequences. The program code instructions **432** may further comprise modeling or predictive routines, equations, algorithms, processes, applications, and/or other programs operable to perform example methods and/or operations described herein. The input devices **426** may be, comprise, or be implemented by a keyboard, a mouse, a joystick, a touchscreen, a track-pad, a trackball, an isopoint, and/or a voice recognition system, among other examples. One or more output devices **428** may also be connected to the interface circuit **424**. The output devices **428** may permit visualization or other sensory perception of various data, such as sensor data, status data, and/or other example data. The output devices **428** may be, comprise, or be implemented by video output devices (e.g., a liquid crystal display (LCD), a light-emitting diode (LED) display, a cathode ray tube (CRT) display, a touchscreen, etc.), printers, and/or speakers, among other examples. The one or more input devices **426** and the one or more output devices **428** connected to the interface circuit **424** may, at least in part, facilitate the HMIs described herein.

The processing device **400** may comprise a mass storage device **430** for storing data and program code instructions **432**. The mass storage device **430** may be connected to the processor **412**, such as via the bus **422**. The mass storage device **430** may be or comprise a tangible, non-transitory storage medium, such as a floppy disk drive, a hard disk drive, a compact disk (CD) drive, and/or digital versatile disk (DVD) drive, among other examples. The processing device **400** may be communicatively connected with an external storage medium **434** via the interface circuit **424**. The external storage medium **434** may be or comprise a removable storage medium (e.g., a CD or DVD), such as may be operable to store data and program code instructions **432**.

41

As described above, the program code instructions 432 may be stored in the mass storage device 430, the main memory 416, the local memory 414, and/or the removable storage medium 434. Thus, the processing device 400 may be implemented in accordance with hardware (perhaps implemented in one or more chips including an integrated circuit, such as an ASIC), or may be implemented as software or firmware for execution by the processor 412. In the case of firmware or software, the implementation may be provided as a computer program product including a non-transitory, computer-readable medium or storage structure embodying computer program code instructions 432 (i.e., software or firmware) thereon for execution by the processor 412. The program code instructions 432 may include program instructions or computer program code that, when executed by the processor 412, may perform and/or cause performance of example methods, processes, and/or operations described herein.

In view of the entirety of the present disclosure, including the figures and the claims, a person having ordinary skill in the art will readily recognize that the present disclosure introduces a well construction system comprising: well construction equipment operable to perform well construction operations; a power supply system operable to output electrical power to the well construction equipment, wherein the power supply system comprises an electrical generator unit; and a control system comprising a processor and a memory storing a computer program code. The computer program code, when executed by the processor, causes the control system to: (A) control an electrical power output level of the power supply system during the well construction operations; and (B) control operation of the well construction equipment during the well construction operations based on: (i) the electrical power output level during the well construction operations; and (ii) an electrical power demand level of the well construction equipment during the well construction operations.

The memory may store a well construction plan that is indicative of a plurality of planned tasks to be performed by the well construction equipment as part of the well construction operations to construct a planned well, and the computer program code, when executed by the processor, may also cause the control system to control the electrical power output level during the well construction operations based on the well construction plan. The well construction plan may be further indicative of a planned electrical power demand of the well construction equipment for performing each of the planned tasks, and the computer program code, when executed by the processor, may also cause the control system to control the electrical power output level during performance of the planned tasks based on the planned electrical power demand. The well construction plan may comprise at least one of: properties of a subterranean formation through which the planned well is to be constructed; a path along which the planned well is to be constructed through the subterranean formation; a depth of the planned well; specifications of the well construction equipment to be used to perform the well construction operations; and specifications of tubulars to be used to perform the well construction operations.

The power supply system may comprise an electrical energy storage unit operable to store the electrical power output by the electrical generator unit, and the computer program code, when executed by the processor, may also cause the control system to control operation of the electrical energy storage unit to alternately, during the well construction operations: store the electrical power output by the

42

electrical generator unit; and output the stored electrical power to the well construction equipment. The well construction system may be connectable with an electrical power grid such that the well construction equipment can receive electrical power from the electrical power grid and the electrical energy storage unit can store the electrical power from the electrical power grid, and the computer program code, when executed by the processor, may also cause the control system to control operation of the electrical energy storage unit to store the electrical power from the electrical power grid.

The present disclosure also introduces a well construction system comprising: well construction equipment operable to perform well construction operations; a power supply system operable to output electrical power to the well construction equipment, wherein the power supply system comprises an electrical generator unit; and a control system comprising a processor and a memory storing a computer program code and a well construction plan, wherein the well construction plan is indicative of a plurality of planned tasks to be performed by the well construction equipment as part of the well construction operations to construct a planned well, and wherein the computer program code, when executed by the processor, causes the control system to control an electrical power output level of the power supply system based on the well construction plan.

The well construction plan may be further indicative of a planned electrical power demand of the well construction equipment for performing each of the planned tasks, and the computer program code, when executed by the processor, may also cause the control system to control the electrical power output level during performance of the planned tasks based on the planned electrical power demand.

The power supply system may comprise an electrical energy storage unit operable to store the electrical power output by the electrical generator unit, and the computer program code, when executed by the processor, may also cause the control system to control operation of the electrical energy storage unit to alternately, during the well construction operations: store the electrical power output by the electrical generator unit; and output the stored electrical power to the well construction equipment. The well construction plan may be further indicative of a planned electrical power demand of the well construction equipment for performing each of the planned tasks, and the computer program code, when executed by the processor, may also cause the control system to control the electrical power output level during performance of the planned tasks based on the planned electrical power demand.

The well construction plan may comprise at least one of: properties of a subterranean formation through which the planned well is to be constructed; a path along which the planned well is to be constructed through the subterranean formation; a depth of the planned well; specifications of the well construction equipment to be used to perform the well construction operations; and specifications of tubulars to be used to perform the well construction operations.

The present disclosure also introduces an apparatus comprising a control system and an electrical energy storage unit. The control system is installable in association with a well construction rig that comprises: well construction equipment operable to perform well construction operations to construct a planned well at a wellsite; and electrical generator units operable to output electrical power to the well construction equipment. The control system is communicatively connectable with the electrical generator units via a communication network of the well construction rig. The

control system comprises a processing device and a memory storing a computer program code. The electrical energy storage unit is installable in association with the well construction rig, electrically connectable with the electrical generator units, and communicatively connectable with the control system via the communication network. The computer program code, when executed by the processor, causes the control system to: (A) control the electrical generator units; and (B) control the electrical energy storage unit to cause the electrical energy storage unit to alternately: (i) store electrical power output by the electrical generator units; and (ii) output the stored electrical power to the well construction equipment during the well construction operations.

The computer program code, when executed by the processor, may also cause the control system to control operation of the well construction equipment based on: an electrical power output level of the electrical generator units; a stored electrical power level of the electrical energy storage units; and an electrical power demand level of the well construction equipment.

The memory may store a well construction plan indicative of a plurality of planned tasks to be performed by the well construction equipment as part of the well construction operations, and the computer program code, when executed by the processor, may also cause the control system to control the electrical generator units and the electrical energy storage unit based on the well construction plan. The well construction plan may be further indicative of a planned electrical power demand of the well construction equipment for performing each of the planned tasks, and the computer program code, when executed by the processor, may also cause the control system to control electrical power output levels of the electrical generator units and the electrical energy storage unit based on the planned electrical power demand. The well construction plan may comprise at least one of: properties of a subterranean formation through which the planned well is to be constructed; a path along which the planned well is to be constructed through the subterranean formation; a depth of the planned well; specifications of the well construction equipment to be used to perform the well construction operations; and specifications of tubulars to be used to perform the well construction operations.

The present disclosure also introduces an apparatus comprising a control system and a hydrogen gas source. The control system is installable in association with a well construction rig that comprises: well construction equipment operable to perform well construction operations to construct a planned well at a wellsite; and electrical generator units operable to output electrical power to the well construction equipment. The control system is communicatively connectable with the electrical generator units via a communication network of the well construction rig. The control system comprises a processing device and a memory storing a computer program code. The hydrogen gas source is installable in association with the well construction rig, fluidly connectable with each engine of the electrical generator units, and communicatively connectable with the control system via the communication network. The hydrogen gas source is operable to output hydrogen gas into each engine. The computer program code, when executed by the processor, causes the control system to: control the electrical generator units; and control the hydrogen gas source to cause the hydrogen gas source to output the hydrogen gas into one or more of the engines.

The computer program code, when executed by the processor, may also cause the control system to control operation of the well construction equipment based on: an electrical power output level of the electrical generator units; and an electrical power demand level of the well construction equipment.

The apparatus may further comprise an electrical energy storage unit installable in association with the well construction rig, electrically connectable with the electrical generator units, and communicatively connectable with the control system via the communication network, wherein the computer program code, when executed by the processor, may also cause the control system to control the electrical energy storage unit to cause the electrical energy storage unit to alternately: store electrical power output by the electrical generator units; and output the stored electrical power to the well construction equipment. The computer program code, when executed by the processor, may also cause the control system to control operation of the well construction equipment based on: an electrical power output level of the electrical generator units; a stored electrical power level of the electrical energy storage units; and an electrical power demand level of the well construction equipment.

The foregoing outlines features of several embodiments so that a person having ordinary skill in the art may better understand the aspects of the present disclosure. A person having ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. A person having ordinary skill in the art should also realize that such equivalent constructions do not depart from the scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A well construction system comprising:

well construction equipment operable to perform well construction operations;

a power supply system operable to output electrical power to the well construction equipment, wherein the power supply system comprises: an electrical power generator unit installed at a wellsite surface; and an electrical energy storage unit operable to store the electrical power output by the electrical power generator unit, wherein the electrical energy storage unit is electrically connected to the electrical power generator unit in parallel, such that the electrical energy storage unit operates as a load to the electrical power generator unit when the electrical energy storage unit stores the electrical power output by the electrical power generator unit; and

a control system comprising a processor and a memory storing a computer program code that, when executed by the processor, causes the control system to:

control an electrical power output level of the power supply system during the well construction operations;

control operation of the well construction equipment during the well construction operations based on: the electrical power output level during the well construction operations; and

an electrical power demand level of the well construction equipment during the well construction operations; and

45

control operation of the electrical power generator unit based on measured load demand by the well construction equipment and the electrical power available from the power supply system during the well construction operations.

2. The well construction system of claim 1 wherein:

the memory further stores a well construction plan that is indicative of a plurality of planned tasks to be performed by the well construction equipment as part of the well construction operations to construct a planned well; and

the computer program code, when executed by the processor, also causes the control system to control the electrical power output level during the well construction operations based on the well construction plan.

3. The well construction system of claim 2 wherein:

the well construction plan is further indicative of a planned electrical power demand of the well construction equipment for performing each of the planned tasks; and

the computer program code, when executed by the processor, also causes the control system to control the electrical power output level during performance of the planned tasks based on the planned electrical power demand.

4. The well construction system of claim 2 wherein the well construction plan comprises at least one of:

properties of a subterranean formation through which the planned well is to be constructed;

a path along which the planned well is to be constructed through the subterranean formation;

a depth of the planned well;

specifications of the well construction equipment to be used to perform the well construction operations; and specifications of tubulars to be used to perform the well construction operations.

5. The well construction system of claim 1 wherein:

the computer program code, when executed by the processor, also causes the control system to control operation of the electrical energy storage unit to alternately, during the well construction operations:

store the electrical power output by the electrical power generator unit; and

output the stored electrical power to the well construction equipment.

6. The well construction system of claim 5 wherein:

the well construction system is connectable with an electrical power grid such that:

the well construction equipment can receive electrical power from the electrical power grid; and

the electrical energy storage unit can store the electrical power from the electrical power grid; and

the computer program code, when executed by the processor, also causes the control system to control operation of the electrical energy storage unit to store the electrical power from the electrical power grid.

7. A well construction system comprising:

well construction equipment operable to perform well construction operations;

a power supply system operable to output electrical power to the well construction equipment,

wherein the power supply system comprises: an electrical power generator unit installed at a wellsite surface; and an electrical energy storage unit operable to store the electrical power output by the electrical power generator unit,

46

wherein the electrical energy storage unit is electrically connected to the electrical power generator unit in parallel, such that the electrical energy storage unit operates as a load to the electrical power generator unit when the electrical energy storage unit stores electrical power output by the electrical power generator unit; and

a control system comprising a processor and a memory storing a computer program code and a well construction plan, wherein:

the well construction plan is indicative of a plurality of planned tasks to be performed by the well construction equipment as part of the well construction operations to construct a planned well; and

the computer program code, when executed by the processor, causes the control system to:

control an electrical power output level of the power supply system based on:

the well construction plan,

measured load demand by the well construction equipment; and

electrical power available from the power supply system during the well construction operations; and

control operation of the well construction equipment during the well construction operations based on:

the electrical power output level during the well construction operations; and

an electrical power demand level of the well construction equipment during the well construction operations.

8. The well construction system of claim 7 wherein:

the well construction plan is further indicative of a planned electrical power demand of the well construction equipment for performing each of the planned tasks; and

the computer program code, when executed by the processor, also causes the control system to control the electrical power output level during performance of the planned tasks based on the planned electrical power demand.

9. The well construction system of claim 7 wherein:

the computer program code, when executed by the processor, also causes the control system to control operation of the electrical energy storage unit to alternately, during the well construction operations:

store the electrical power output by the electrical power generator unit; and

output the stored electrical power to the well construction equipment.

10. The well construction system of claim 9 wherein:

the well construction plan is further indicative of a planned electrical power demand of the well construction equipment for performing each of the planned tasks; and

the computer program code, when executed by the processor, also causes the control system to control the electrical power output level during performance of the planned tasks based on the planned electrical power demand.

11. The well construction system of claim 7 wherein the well construction plan comprises at least one of:

properties of a subterranean formation through which the planned well is to be constructed;

a path along which the planned well is to be constructed through the subterranean formation;

a depth of the planned well;

47

specifications of the well construction equipment to be used to perform the well construction operations; and specifications of tubulars to be used to perform the well construction operations.

12. An apparatus comprising:

a control system installable in association with a well construction rig, wherein:

the well construction rig comprises:

well construction equipment operable to perform well construction operations to construct a planned well at a wellsite; and

a power supply system operable to output electrical power to the well construction equipment, the power supply system comprising:

electrical power generator units installed at a wellsite surface operable to output electrical power to the well construction equipment; and

an electrical energy storage unit operable to store the electrical power output by the electrical power generation units, wherein the electrical energy storage unit is electrically connected to the electrical power generator units in parallel, such that the electrical energy storage unit operates as a load to the electrical power generator units when the electrical energy storage unit stores electrical power output by the electrical power generator units, and wherein the electrical energy storage unit is communicatively connected with the control system via a communication network of the well construction rig;

the control system is communicatively connectable with the electrical power generator units via the communication network; and

the control system comprises a processor and a memory storing a computer program code,

wherein the computer program code, when executed by the processor, causes the control system to:

control an electrical power output level of the power supply system during well construction operations;

control operation of the well construction equipment during the well construction operations based on: the electrical power output level during the well construction operations; and

an electrical power demand level of the well construction equipment during the well construction operations; and

control operation of the electrical power generator units based on measured load demand by the well construction equipment and electrical power available from the power supply system during the well construction operations; and

control the electrical energy storage unit to cause the electrical energy storage unit to alternately: store the electrical power output by the electrical power generator units; and

output the stored electrical power to the well construction equipment during the well construction operations.

13. The apparatus of claim 12 wherein:

the memory further stores a well construction plan; the well construction plan is indicative of a plurality of planned tasks to be performed by the well construction equipment as part of the well construction operations; and

the computer program code, when executed by the processor, also causes the control system to control the

48

electrical power generator units and the electrical energy storage unit based on the well construction plan.

14. The apparatus of claim 13 wherein:

the well construction plan is further indicative of a planned electrical power demand of the well construction equipment for performing each of the planned tasks; and

the computer program code, when executed by the processor, also causes the control system to control the electrical power output of the electrical power generator units and the electrical energy storage unit based on the planned electrical power demand.

15. The apparatus of claim 13 wherein the well construction plan comprises at least one of:

properties of a subterranean formation through which the planned well is to be constructed;

a path along which the planned well is to be constructed through the subterranean formation;

a depth of the planned well;

specifications of the well construction equipment to be used to perform the well construction operations; and specifications of tubulars to be used to perform the well construction operations.

16. An apparatus comprising:

a control system installable in association with a well construction rig, wherein:

the well construction rig comprises:

well construction equipment operable to perform well construction operations to construct a planned well at a wellsite; and

electrical power generator units operable to output electrical power to the well construction equipment, wherein the electrical power generator units are installed at a wellsite surface;

the control system is communicatively connectable with the electrical power generator units via a communication network of the well construction rig; and the control system comprises a processor and a memory storing a computer program code; and

an electrical energy storage unit installable in association with the well construction rig, electrically connectable with the electrical power generator units, and communicatively connectable with the control system via the communication network,

wherein the electrical energy storage unit is electrically connected to the electrical power generator units in parallel, such that the electrical energy storage unit operates as a load to the electrical power generator units when the electrical energy storage unit stores the electrical power output by the electrical power generator units; and

a hydrogen gas source installable in association with the well construction rig, fluidly connectable with each engine of the electrical power generator units, and communicatively connectable with the control system via the communication network, wherein the hydrogen gas source is operable to output hydrogen gas into each engine;

wherein the computer program code, when executed by the processor, causes the control system to:

control the electrical power generator units; and

control the hydrogen gas source to cause the hydrogen gas source to output the hydrogen gas into one or more of the engines.

17. The apparatus of claim 16 wherein the computer program code, when executed by the processor, also causes the control system to control operation of the well construction equipment based on:

- an electrical power output level of the electrical power generator units; and
- an electrical power demand level of the well construction equipment.

18. The apparatus of claim 16, wherein the computer program code, when executed by the processor, also causes the control system to control the electrical energy storage unit to cause the electrical energy storage unit to alternately:

- store electrical power output by the electrical power generator units; and
- output the stored electrical power to the well construction equipment.

19. The apparatus of claim 18 wherein the computer program code, when executed by the processor, also causes the control system to control operation of the well construction equipment based on:

- an electrical power output level of the electrical power generator units;
- a stored electrical power level of the electrical energy storage units; and
- an electrical power demand level of the well construction equipment.

* * * * *