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Inventor(s)	Hinderliter; Brandon N. et al.

Microgrid electrical load management

Abstract

A system for completing a well, including a generator, and a plurality of electric load components, each electric load component powered by the generator. The system further includes a load shedding control panel that monitors the generator and, if the generator loses functionality, is capable of deactivating one or more of the plurality of electric load components to reduce the electric load.

Inventors: **Hinderliter; Brandon N. (Houston, TX), Oehring; Jared (Houston, TX)**

Applicant: **U.S. Well Services, LLC** (Houston, TX)

Family ID: **1000008765273**

Assignee: **U.S. WELL SERVICES, LLC (Willow Park, TX)**

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Primary Examiner: Gay; Jennifer H

Attorney, Agent or Firm: Abel Schillinger, LLP

Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. patent application Ser. No. 17/466,261 filed Sep. 3, 2021 titled "MICROGRID ELECTRICAL LOAD MANAGEMENT," now U.S. Pat. No. 11,851,999 issued Dec. 26, 2023, which is a continuation of U.S. patent application Ser. No. 16/268,030 filed Feb. 5, 2019 titled "MICROGRID ELECTRICAL LOAD MANAGEMENT," now U.S. Pat. No. 11,114,857 issued Sep. 7, 2021, which claims priority to and the benefit of U.S. Provisional Application Ser. No. 62/626,614 filed Feb. 5, 2018 titled "MICROGRID ELECTRICAL LOAD MANAGEMENT," the full disclosures of which are hereby incorporated herein by reference in their entirety for all intents and purposes.

BACKGROUND
1. Technical Field
(1) This disclosure relates generally to hydraulic fracturing and more particularly to systems and methods for configuring high horsepower pumping systems.
2. Background
(2) With advancements in technology over the past few decades, the ability to reach unconventional sources of hydrocarbons has tremendously increased. Horizontal drilling and hydraulic fracturing are two such ways that new developments in technology have led to hydrocarbon production from previously unreachable shale formations. Hydraulic fracturing (fracturing) operations typically require powering numerous components in order to recover oil and gas resources from the ground. For example, hydraulic fracturing usually includes pumps that inject fracturing fluid down the wellbore, blenders that mix proppant, chemicals, and the like into the fluid, cranes, wireline units, and many other components that all perform different functions to carry out fracturing operations.
(3) Usually in fracturing systems, the fracturing equipment runs on diesel motors or by other internal combustion engines. Such engines may be very powerful, but have certain disadvantages. Diesel is more expensive, is less environmentally friendly, less safe, and heavier to transport than natural gas. For example, diesel engines are very heavy, and so require the use of a large amount of heavy equipment, including trailers and trucks, to transport the engines to and from a well site. In addition, such engines are not clean, generating large amounts of exhaust and pollutants that may cause environmental hazards, and are extremely loud, among other problems. Onsite refueling, especially during operations, presents increased risks of fuel leaks, fires, and other accidents. The

large amounts of diesel fuel needed to power traditional fracturing operations require constant transportation and delivery by diesel tankers onto the well site, resulting in significant carbon dioxide emissions.

(4) Some systems have tried to eliminate partial reliance on diesel by creating bi-fuel systems. These systems blend natural gas and diesel, but have not been very successful. It is thus desirable that a natural gas powered fracturing system be used in order to improve safety, save costs, and provide benefits to the environment over diesel powered systems. Because of the problems associated with diesel and bi-fuel systems, some operators have turned to electric motors connected to turbine generators to power the pumps and other equipment associated with hydraulic fracturing operations. Electric hydraulic fracturing operations may utilize multiple turbine generators, ultimately powering multiple pumps.

(5) One problem with electric powered hydraulic fracturing fleets is that if a single turbine generator fails, it will typically shutdown completely within a few seconds. If the power demand from the fracturing equipment is higher than the output of the remaining turbine generators, the remaining generators will begin to shut down within a few seconds as well. The reaction times by human operators are almost always too slow to manually shutdown pumps, thereby shedding electrical load, in time to prevent a blackout.

(6) In a worst case scenario, this can lead to the pumps stopping instantly while pumping proppant laden fluid (often called “slurry” or “dirty fluid”) so that a flush cannot be completed. Once fluid stops moving, the proppant begins to fall out of suspension and can accumulate in the wellbore. Horizontal wells have a vertical section before curving to the horizontal segment along the targeted shale formation. If proppant drops out of the slurry, it will slowly fall down the vertical segment and pile up at the curve (or heel) of the well and plug it off. Even if a partial flush is completed and proppant laden fluid is only in the horizontal segment of the well, proppant dropout can till cause plugging issues or can partially plug off the perforations in the well casing. This can also cause extended down time, or non-productive time, where several cycles of flowing the well back and performing low rate injection tests can be required to clear the well of proppant and open the perforations back up.

SUMMARY

(7) One aspect of the present technology provides a system for completing a well. The system includes a generator and a plurality of electric load components, each electric load component powered by the generator, the system also includes a load shedding control panel that monitors the generator and, if the generator loses functionality, is capable of deactivating one or more of the plurality of electric load components to reduce the electric load.

(8) In some embodiments, the technology can include a switchgear positioned between the generator and the plurality of electric load components to distribute power between the generator and the plurality of electric load components. In addition, the generator can be a natural gas turbine generator, a natural gas generator, a diesel generator, or a combination of these or other power sources.

(9) According to some embodiments, the electric load components can be selected from the group consisting of electric hydraulic fracturing pumps (e.g., triplex frac pumps, quintuplex frac pumps, dual fracturing pump iots, long stroke intensifier pumps, or any other style of frac pump used to move hydraulic fracturing fluid), a blender, sand equipment, a hydration unit, and a data van. Furthermore, the load shedding panel can prioritize the order in which the plurality of electric load components will be deactivated, and can be programmed to deactivate the blender after other electric load components are deactivated. In yet further embodiments, the generator can be in selective electrical communication with a power grid.

(10) Another aspect of the present technology provides a system for completing a well, including a generator, a plurality of hydraulic fracturing equipment components, each of the plurality of hydraulic fracturing equipment components powered by the generator, and an electric drilling rig,

the electric drilling rig powered by the generator. The system can further include a load shedding control panel that monitors the generator and, if the generator loses functionality, is capable of deactivating one or more of the plurality of hydraulic fracturing equipment components or the electric drilling rig or other oilfield equipment to reduce the electric load.

(11) In some embodiments, the technology can include a switchgear positioned between the generator and the plurality of hydraulic fracturing equipment components, and between the generator and the electric drilling rig, to distribute power between the generator and the plurality of hydraulic fracturing equipment components, and between the generator and the electric drilling rig. In addition, the generator can be a natural gas turbine generator, a natural gas generator, a diesel generator, or a combination of these or other power sources.

(12) According to some embodiments, the hydraulic fracturing equipment components can be selected from the group consisting of electric hydraulic fracturing pumps (e.g., triplex frac pumps, quintuplex frac pumps, dual fracturing pumps, long stroke intensifier pumps, or any other style of frac pump used to move hydraulic fracturing fluid), a blender, sand equipment, a hydration unit, and a data van. Furthermore, the load shedding panel can prioritizes the order in which the plurality of hydraulic fracturing equipment components and the electric drilling rig or other oilfield equipment will be deactivated, and can be programmed to deactivate the blender after other hydraulic fracturing equipment components are deactivated. In yet further embodiments, the generator can be in selective electrical communication with a power grid.

(13) Yet another aspect of the technology provides a method of completing a well. The method includes the steps of powering a plurality of hydraulic fracturing equipment components with a generator, monitoring the generator to determine when the generator loses functionality, and when the generator loses functionality, selectively deactivating one or more of the plurality of hydraulic fracturing equipment components to decrease the load.

(14) According to some embodiments, the method can further include powering an electric drilling rig or other oilfield equipment with a generator. Furthermore, the plurality of hydraulic fracturing equipment can include at least one blender, and the method can further include the step of prioritizing the deactivation of the plurality of hydraulic fracturing equipment components so that the at least one blender is deactivated only after other hydraulic fracturing equipment is deactivated.

(15) In alternate embodiments, the method can include distributing power from the generator to a power grid, and distributing power between the generator and the plurality of hydraulic fracturing equipment components with a switchgear. Furthermore, in yet further embodiments, the method can include a load shedding control panel that monitors the generator to determine when the generator loses functionality.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) The present technology will be better understood on reading the following detailed description of non-limiting embodiments thereof, and on examining the accompanying drawings, in which:

(2) FIG. **1** is a schematic diagram of a load shedding control system according to an embodiment of the present technology;

(3) FIG. **2** is schematic diagram of a load shedding control system according to an alternate embodiment of the present technology;

(4) FIG. **3** is a schematic diagram of a load shedding control system according to yet another embodiment of the present technology, where the load shedding control package communicates with turbine generators; and

(5) FIG. **4** is a schematic diagram of a load shedding control system according to another alternate

embodiment of the present technology.
(6) While the disclosure will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the disclosure to that embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalents, as may be included within the spirit and scope of the disclosure as defined by the appended claims.

DETAILED DESCRIPTION

(7) The foregoing aspects, features, and advantages of the present disclosure will be further appreciated when considered with reference to the following description of embodiments and accompanying drawings. In describing the embodiments of the disclosure illustrated in the appended drawings, specific terminology will be used for the sake of clarity. However, the disclosure is not intended to be limited to the specific terms used, and it is to be understood that each specific term includes equivalents that operate in a similar manner to accomplish a similar purpose.
(8) When introducing elements of various embodiments of the present disclosure, the articles “a”, “an”, “the”, and “said” are intended to mean that there are one or more of the elements. The terms “comprising”, “including”, and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Any examples of operating parameters and/or environmental conditions are not exclusive of other parameters/conditions of the disclosed embodiments. Additionally, it should be understood that references to “one embodiment”, “an embodiment”, “certain embodiments”, or “other embodiments” of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Furthermore, reference to terms such as “above”, “below”, “upper”, “lower”, “side”, “front”, “back”, or other terms regarding orientation or direction are made with reference to the illustrated embodiments and are not intended to be limiting or exclude other orientations or directions. Additionally, recitations of steps of a method should be understood as being capable of being performed in any order unless specifically stated otherwise. Furthermore, the steps may be performed in series or in parallel unless specifically stated otherwise.
(9) Embodiments of the present disclosure describe systems and methods for various pump configurations to produce greater horsepower (HP) output with a smaller footprint at a well site. In certain embodiments, various components may be arranged on a common support structure, such as a trailer or skid. For example, the trailer may include a transformer, variable frequency drive (VFD), soft start, and pump. In such embodiments, the total area available for pumps on the trailer may be decreased due to the support equipment, and as a result, the horsepower output from the pump may be reduced because of its size. In various embodiments, a separate skid or trailer may be utilized for certain support components to thereby enable larger pumps or more pumps to be positioned on the pump trailer to increase the total horsepower output and reduce the number of pump trailers arranged at the well site.
(10) Embodiments of the present disclosure describe systems and methods for pumping configurations utilizing electric powered pumps that produce horsepower greater than or equal to diesel-powered pumping configuration. Diesel-powered systems are noisy and generate pollution. Moreover, transportation of fuel to well sites may be costly and availability of fuel may delay or otherwise bottleneck fracturing operations. In various embodiments, electric pumping configurations include trailers or skids with a pump and a VFD mounted on a single skid or trailer. In certain embodiments, the VFD or softstart may be moved to a separate auxiliary skid to increase the room available on the trailer or skid housing the pump. As a result, multiple pumps may be situated on the skid or trailer, or larger pumps may be situated on the skid or trailer. In various embodiments, a single trailer or skid may have a capacity for a 6000+ HP output utilizing a variety of configurations such as a single pump with multiple electric motors, a single electric motor powering a large pump, a large electric motor powering multiple pumps, or the like.
(11) In various embodiments, the pumps utilized with the disclosed configurations may include

non-standard fluid ends (e.g., a fluid manifold with valves and seats to isolate a suction side and high pressure discharge side without allowing back flow). By way of example only, the fluid ends may include more than 3 plungers (e.g., triplex) or more than 5 plungers (e.g., quintuplex) or plunger stroke lengths longer than 11 inches. For example, the fluid ends may be septenplex (7 plungers), novenplex (9 plungers), undenplex (11 plungers), tredenplex (13 plungers), or include any other reasonable number of plungers. Size constraints and the like have produced difficulty utilizing such pumps in other systems. However, by adjusting the position of various support equipment for the pumps, such as VFDs, transformers, and motor control centers (MCCs), the trailer or skid may have sufficient size to accommodate larger or non-standard pumps for use with hydraulic fracturing. The pump may be of an intensifier style that utilizes hydraulic power to generate hydraulic horsepower using a VFD, softstart, or other controller for the electric pumps of the hydraulic system.

(12) In various embodiments, the pumping configurations described herein may include a support skid. This support skid may include auxiliary components for operating the pumps, such as the VFDs, transformers, MCCs, and the like to thereby free up space on the skid or trailer housing the pumps for various additional different configurations, such as more pumps or larger pumps. While referred to herein as “support skids” it should be appreciated that the components associated with the support skids may be mounted on a skid or trailer. That is, the term “support skid” should not be interpreted as limiting the base or support structure to only a skid and other support structures, such as pads, trailers, truck beds, and the like may also be utilized and fall within the scope of the embodiments disclosed herein. Moreover, references to “pump trailers” should be interpreted as including embodiments where the support structure for the pumps and/or associated pumping equipment includes a trailer, a skid, a pad, a truck bed, or any other reasonable support structure.

(13) Various embodiments utilize VFDs in order to control and monitor operation of the electric fracturing pumps. The VFDs may include soft stalls for improved operation. The soft stall allows the VFD to “disengage” the motor for a short amount of time (such as milliseconds) instead of tripping the VFD off to protect the drive and motor. Due to fluctuations in the wellhead pressure and pump fluid rate, if the VFD is near its upper limitations on torque a small fluctuation of pressure can cause the VFD to “trip” or shut down to protect itself to prevent damage. The soft stalls allow the VFD to stall temporarily then reengage the motor instead of shutting down completely. These “soft stalls” are unnoticed by the operator and are so quick that total fluid rate is not affected. This feature allows operation of the VFDs and motors at higher horsepower without fear of suffering an unexpected shutdown. Rated hydraulic horsepower (HHP) may be increased from 1,600 HP to 1,700 HP or more. In various embodiments, the soft stall is a software setting implemented as an executable instruction stored on a non-transitory machine readable memory and initiated by an associated processor of a control system.

(14) According to systems of the present technology, electric motors may also be used to power other equipment associated with hydraulic fracturing operations. For example, the motors can power auxiliary equipment, such as blenders, proppant equipment, hydration units, etc.

(15) The present technology relates to the process of automating the shedding and addition of electrical load and power generation from a mobile electric microgrid to prevent blackouts. In some embodiments, a software control package can be implemented to allow equipment that draws power to be automatically shut down when power demand is too high for the power generation equipment to supply, or if a generator failure causes an unexpected loss in available power supply. To prevent a black out (such as when all generators shut down due to too high of a power demand), certain equipment can be quickly shut down. This process is advantageous because it can prevent costly and potentially dangerous black outs, and can allow operators to prioritize equipment to be shed from the grid during these situations. The software controls can rapidly drop non-process critical equipment to allow power to be supplied to critical equipment until the last possible moment. The equipment can then be re-enabled for use by the operators once extra power

generation is available. The control system can also automate the start-up and addition of any standby power generators to a microgrid.

(16) For example, in one example hypothetical situation, there can be 4 turbine generators on a single power grid capable of supplying 23 MW of power to 16 frac pumps and 1 blender, as well as smaller auxiliary equipment. During operation, one turbine generator can suffer an unexpected mechanical failure and shut down during a frac stage where the power draw is 18 MW. This can happen very quickly. The power output capability of only 3 turbine generators in such a situation may be as low as 17 MW. As a result, within moments, the remaining turbine generators would be overdrawn and shutdown to protect themselves from failure. This shutdown in turn could cause the frac pumps to lose power, and they in turn would cease pumping fluid into the well. Lack of fluid circulation in the well could lead to a screenout, which occurs when fluid velocity is lost and the proppant drops out of the fluid and plugs the wellbore, causing extended downtime at great expense to clean out the well to resume operations.

(17) In another non-limiting example, there can be a single turbine generator on a single power grid capable of supplying 30 MW of power to 22 frac pumps and 2 blenders, as well as smaller auxiliary equipment. During operation, the power available to one turbine generator can be reduced to only 20 MW of power. This can happen very quickly. If the running equipment draws greater than 20 MW of power, the turbine could be overdrawn and shutdown to protect itself from failure. This shutdown in turn could cause the frac pumps to lose power, and they in turn would cease pumping fluid into the well. Lack of fluid circulation in the well could lead to a screen out, which occurs when fluid velocity is lost and the proppant drops out of the fluid and plugs the wellbore, causing extended downtime at great expense to clean out the well to resume operations.

(18) With the control system of the present technology, on the other hand, the power grid of the above hypothetical situations can automatically shut down one or two frac pumps at the time of the unexpected mechanical failure. This could lower the power draw requirement from 18 MW to, for example, 16 MW, thereby preventing a blackout and allowing the wellbore to be flushed properly, which would in turn prevent a screenout event. The order of shedding equipment can be prioritized. For example, the order can be preselected to ensure that the blender is the last piece of equipment dropped off the grid.

(19) One advantage of the present technology is that is can provide management of standby generators during peak power demand. For example, in certain embodiments, equipment can have switch gear units equipped with extra input breakers allowing use of both turbine generators, as well as back-up diesel generators to power the system. The load management control system can be capable of automatically starting the back-up diesel generators once the power load reaches a specified percentage of the maximum capability of the turbine generators. For example, once the power draw of the frac equipment reaches about 80% of the capability of the turbine generators (in some embodiments, this could be about 18.5 MW), the control system can trigger the auto ignition of the spare diesel generators, but not close the breaker connecting them to the grid. Once the power load reaches about 90% of the turbine generator's capability, the control system can rev up the diesel generators, phase match the power, and close the breakers connecting to the power grid. In one specific example, if two 2000 kW diesel generators are connected, total power generation can reach 27 MW, and can power the frac fleet at peak power demand instead of shedding load, or forcing the frac pump operators to back down on fluid rate. Operating in this manner can eliminate or reduce the need for backup generators to idle constantly, thereby saving time, fuel, and wear and tear on the backup generators.

(20) In certain embodiments, the backup generators can be automated. For example, the system can be designed so that if one turbine generator fails and shuts down and the load shedding system automatically shuts down two frac pumps (as discussed in the above example), the system can start up the back-up diesel generators and connect them to the grid, then enable the previously shutdown frac pumps to begin operation again. This will allow the pump operator to then begin using those

frac pumps when sufficient power is available. Doing this will allow the frac stage to be completed normally instead of being forced to flush the well and shut down without properly completing the stage.

(21) The technology herein shown and described is beneficial because it allows an operator to complete a fracturing stage, which usually consists of 2-4 hours of non-stop fluid pumping at the designed fluid rate, until the designed amount of proppant is displaced down the wellbore and into the shale formation. If the stage cannot be completed, in this case due to loss of power generation, the second best scenario is to flush the wellbore, which means to stop proppant delivery and to pump “clean” fluid only (non-proppant laden fluid) into the wellbore until all proppant laden fluid is displaced into the shale formation. If this is done, pumping can be stopped without any adverse consequences such as a screen out event, but the frac stage is usually considered incomplete. Flushing the well can take up to 10 minutes depending on the depth of the well and the fluid rate being pumped.

(22) If a single turbine generator fails, it will typically shutdown completely within a few seconds. If the power demand from the fracturing equipment is higher than the output of the remaining turbine generators, the remaining generators will begin to shut down within a few seconds as well. The reaction times by human operators are almost always too slow to manually shutdown pumps, thereby shedding electrical load, in time to prevent a blackout. Thus, the software driven embodiments of the present technology are advantageous because they can greatly increase reaction times.

(23) In a worst case scenario, this can lead to the pumps stopping instantly while pumping proppant laden fluid (often called “slurry” or “dirty fluid”) so that a flush cannot be completed. Once fluid stops moving, the proppant begins to fall out of suspension and can accumulate in the wellbore. Horizontal wells have a vertical section before curving to the horizontal segment along the targeted shale formation. If proppant drops out of the slurry, it will slowly fall down the vertical segment and pile up at the curve (or heel) of the well and plug it off. Even if a partial flush is completed and proppant laden fluid is only in the horizontal segment of the well, proppant dropout can still cause plugging issues or can partially plug off the perforations in the well casing. This can also cause extended down time, or non-productive time, where several cycles of flowing the well back and performing low rate injection tests can be required to clear the well of proppant and open the perforations back up. If a blackout occurs, such that all frac pumps lose power and stop functioning, a shutdown turbine can take 15-30 minute to get operational again, while multiple turbines can take hours to restart and phase match to allow breakers to close to a common bus, or switch gear unit.

(24) Another advantage of the present technology is that it provides for prioritized equipment shutdown. For example, the load management control system shown and described herein can save many hours of down time by preventing an electrical blackout. If, however, the electrical load that the system sheds is the auxiliary unit (which can power, for example, the blender, hydration unit, sand equipment, etc.) then the fluid flow will stop as well. The blender draws on low pressure water (typically about 20-60 psi), mixes in chemicals and proppants, and discharges the slurry at a high enough pressure (typically about 100-140 psi) to prevent cavitation in the fracturing pumps. A single blender can also be capable of providing up to 130 bpm of fluid (BPM=barrels per minutes, a barrel is 42 gallons of fluid and is a standard unit of measurement in US oilfield operations). On the other hand, a single frac pump is capable of taking 100 psi fluid from the blender and discharge it at up to 15,000 psi, but it can typically only pump at a max rate of about 5 to 12 bpm. If, therefore, a fracturing stage design requires 100 bpm of fluid rate then up to 20 frac pumps are required, but only 1 blender. Due to this, it is advantageous to prioritize the order of load shedding to make sure that the blender is shut down last, or not at all, even if it results in a blackout.

(25) The system of certain embodiments of the present technology can allow the operator to preselect equipment to shed in a power loss situation. Operators can designate the blender to be the

last piece of equipment to lose power (or to not lose power at all), and can choose frac pumps to be shed first that have mechanical issues such as worn out seats and valves, are experiencing high cavitation, cooling issues, have fluid leaks, or are overdue for routine maintenance.
(26) It is common to have supplemental diesel powered frac pumps in fluid communication with the electric pumps. In some embodiments, the load shedding control system of the present technology can also recognize diesel pumps, and avoid shutting them down in an attempt to shed electrical load. It is also common to have energized electric pumps which are operable but are not actively pumping. De-energizing these pumps does not lower the electrical power load, and thus the control system can ignore them and only shutdown prioritized pumps which are consuming electrical power.
(27) The embodiment of FIG. **1** shows a simplified block diagram of an embodiment of a hydraulic fracturing system **100**, including a tie breaker load sharing management arrangement. In the illustrated embodiment, a power generation section **102** includes five turbine generators **104**A-E and three diesel backup generators **105**A-C arranged to produce electrical energy at approximately 13.8 kV and generate more than approximately 20 MW of power depending on demand, size, and the like. That is, different types of generators may be arranged at the well site and produce different quantities of electrical energy. Furthermore, different sizes of generators may be utilized in order to accommodate size and space restrictions at the well site. It should be appreciated that other equipment, such as compressors, filters, heaters, electronic equipment rooms and the like can be part of the system, but have been omitted from the figures for clarity.
(28) The illustrated embodiment further includes a power distribution section **106** including switch gear units **108**A-C for protection and distribution, as well as auxiliary unit **110**. As shown, the generators **104**A-E produce electrical energy at 13.8 kV for transmission to the switch gear units **108**A-C. Thereafter, step down transformers (not shown) can receive and convert the energy to 600 V, which is distributed to pumps **112**. As shown, the auxiliary unit **110** can be utilized to step down the energy for the associated fracturing equipment, such as a data van **114**, blender **116**, sand equipment **118**, and a hydration unit **120**. In various embodiments, the auxiliary unit(s) **110** may include transformers to step down the energy to 600 V, 240 V, or any other reasonable voltage output.
(29) Continuing with FIG. **1**, the illustrated embodiment includes hydraulic fracturing equipment, such as the illustrated pumps **112**, data van **114**, blenders **116**, sand equipment **118**, and hydration unit **120**. It should be appreciated that various components have been simplified and/or removed for clarity. Moreover, the embodiment illustrated in FIG. **1** is not intended to be limiting. For instance, more than **10** frac pump units may be arranged at a well site. Moreover, multiple data vans, blenders, sand equipment, and hydration units may be utilized. The illustrated pumps **112** can be twin frac pumps. The twin frac pumps may be arranged on a common skid or trailer and receive energy from the transformers. It should be appreciated that the pumps **112** may be configured to operate at different voltages, such as 600 V, 13.8 kV, 4,160 V, or any reasonable voltage. Moreover, in embodiments the pumps **112** may be singular pumps mounted on a trailer or skid. However, in embodiments that utilize the twin frac pumps, the trailer or skid may include two fully independent, electrically powered fluid pumps. In various embodiments, the illustrated fleet is capable of generating approximately 16,000 HP for fracturing jobs. Different configurations, for example of the pumps, may enable more than approximately 20,000 HP.
(30) The tie breaker load sharing management arrangement shown in FIG. **1** is similar in idea to the prioritized equipment shutdown discussed above. With a load shedding control system, it is less risky to provide power to equipment performing other operations. For example, on some larger well sites, it is possible to perform hydraulic fracturing operations on completed wells while a drilling rig is still operating on other wells. Drilling operations can be more sensitive than fracturing operations, and can be less tolerant of unplanned power losses.
(31) In FIG. **1**, the power generation components include generators **104**A-E and diesel backup

generators **105**A-C. Power distribution components include the switch gears **108**A-C and an auxiliary unit **110**. The remaining components act as the power load. The arrows depict the electrical cable arrangement and the normal direction of electrical power flow. The equipment shown has tie breakers **122**A, **122**B for load sharing, as well as load shedding software in one embodiment (discussed in greater detail below). Switch gear tie breakers **122**A, **122**B allow the switch gear to act as a single bus (or circuit) and allow for phase matching and breaker protection. One aspect of the present technology is that the diesel backup generators **105**A-C can be directly connected to the switch gears **108**A-C to be used for load sharing, and they can be automated in the event of load shedding.

(32) In the embodiment shown in FIG. **1**, the microgrid provides power for a hydraulic fracturing fleet **100** and a drilling rig **124**. In some embodiments, the drilling rig **124** can require up to about 4 MW of power, while a frac fleet for certain formations can require around about 22 MW of electrical power. For normal fracturing operations, the turbine generator **104**A and switch gear **108**A may not be needed.

(33) Each switch gear **108**A-C can be electrically connected with a tie breaker **122**A, **122**B. This is where smart automated management of power distribution comes into play. If one of the turbine generators **104**B-E fail, the rig turbine generator **104**A can supplement power to the frac equipment, but will prioritize the drilling rig **124**, and will open the breaker **122**A to the frac equipment if the power demand becomes too much and threatens shutting down the turbine **104**A and causing a black out. This will force the frac equipment to begin load shedding to lower power demand.

(34) The opposite is also true. That is, if the rig turbine **104**A fails, the frac turbines **104**B-E can provide power through the tie breaker **122**A to ensure that drilling operations are uninterrupted. If there is not enough power available for simultaneous operations, the frac side can be forced to start load shedding to prevent a black out. The example herein is true if the diesel backup generators **105**A-C are unable to provide enough supplementary power, or if they have failed as well (e.g., won't start due to cold weather, are out of fuel, take too long to start up and warm up, etc.). If the load shedding is not quick enough, or if there are multiple failed generators, the tie breaker **122**A between the drilling rig and the frac equipment can be opened. This creates two independent circuits where failures occurring on one will not affect the other.

(35) Referring now to FIG. **2**, there is shown an alternative embodiment of a hydraulic fracturing system **200**, including a tie breaker load sharing management arrangement. In the illustrated embodiment, a power generation section **202** includes four turbine generators **204**A-D and two diesel backup generators **205**A, **205**B arranged to produce electrical energy at approximately 13.8 kV and generate more than approximately 20 MW of power depending on demand, size, and the like. That is, different types of generators may be arranged at the well site and produce different quantities of electrical energy. Furthermore, different sizes of generators may be utilized in order to accommodate size and space restrictions at the well site. It should be appreciated that other equipment, such as compressors, filters, heaters, electronic equipment rooms and the like can be part of the system, but have been omitted from the figures for clarity.

(36) The illustrated embodiment further includes a power distribution section **206** including switch gears **208**A, **208**B for protection and distribution. As shown, the generators **204**A-D produce electrical energy at 13.8 kV for transmission to the switch gears **208**A, **208**B. Thereafter, step down transformers can receive and convert the energy to 600 V, which is distributed to pumps **112**. An auxiliary unit can be utilized to step down the energy for associated fracturing equipment, such as, for example a data van, blender, sand equipment, and a hydration unit. In various embodiments, the auxiliary unit may include transformers to step down the energy to 700 V, 600 V, 240 V, or any other reasonable voltage output.

(37) One advantage of the present technology is that, with this level of power distribution management, it is possible to safely and reliably connect the mobile microgrid to a local utility

grid. Typically, connecting to a utility power grid is risky due to the power demands of a frac fleet being too large and too unstable for a utility grid to handle without itself becoming unstable. Now, with an automatically managed utility tie breaker **222** and load shedding control software, it is possible to connect to the power grid to supply excess power to the utility when available. The opposite is true as well. That is, it is possible to draw power from the utility grid to supplement the oilfield equipment when the utility grid is far from its peak demand. This is without the risk of a black out if the utility needs to disconnect or experiences a service interruption. If this happens, and the generators **204**A-D can't make up the difference in power supply, the control software can simply load shed equipment to keep fluid moving.

(38) One mode of practicing the processes herein shown and described is to have a central datavan **114** (shown in FIG. **1**), or data unit for the fracturing equipment control load shedding software. The datavan **114** can already have a resident software control package that controls, monitors, and records all activity of the fracturing equipment, and is already able to remotely shut down frac pumps. It can also be able to monitor turbine power load and can remotely open switch gear breakers with operator input.

(39) In some embodiments, the system can have the ability to automatically start up and connect the diesel backup generators **205**A, **205**B based on power demand, to instantly shut down equipment based off of prioritization, and to automatically open or close switch gear breakers. The preference to shed load can be to simply stop the electric motor(s) without opening the switch gear breakers. This may allow quick re-energization of the equipment once power is restored or a backup source of power is connected (e.g., the diesel backup generators, a non-frac generator on an adjacent switch gear, or a utility grid). This can also reduce wear and tear on the large breakers with physically moving parts, and reduces the risk of an arc flash inside the switch gear **108**A, **108**B. The tie breakers **222** for load sharing can be controlled by operating the physical breakers to make the electrical connections.

(40) Referring now to FIG. **3**, alternate embodiments of the present technology include control software and hardware that can be installed in switch gear trailers. Such software and hardware can include a load shedding panel **326** in communication with switchgear units **308**A, **308**B and turbine generators **304**A-D, as well as backup diesel generator **305**. The load shedding panel **326** can also be in communication with programming terminals **328**A, **328**B, such as a computer, and a distributed control (DCS) system or supervisory control and data acquisition (SCADA) system **330**. In some embodiments, communication between the programming terminal **328** and the load shedding panel **326**, and between the DCS/SCADA system **330** and the load shedding panel **326** can be via Ethernet or other cable **332**. In other embodiments, such communication can be wireless.

(41) The software and hardware shown in FIG. **3** can have individual breaker power load information, and control over opening and closing breakers without the need for communication cables to a datavan. In addition, in some embodiments, it may also be possible to install the load shedding control package in the turbine generators **304**A-D. Advantageously, the system of FIG. **3** can be set up for controlling and monitoring power generation only, without the consideration of the frac fleet or other types of oilfield equipment.

(42) At least two alternate methods can be used for shutting down electrical equipment to shed power loads. These include 1) opening the associated breaker for that particular piece of equipment, or 2) by signaling the onboard control system to stop the large electric motor and any associated electrical loads. Opening the breaker will shed all electrical load by cutting off power to the entire piece of equipment. On the other hand, signaling the onboard control system to shut down the VFD and drive motor will cut most of the power load while keeping the control system energized so it can be quickly restarted and process monitoring instruments can still be recording and reporting information, such a pressures and temperatures.

(43) While a single blender is shown and described in individual figures in this disclosure, the present technology contemplates perform load shedding with multiple auxiliary units and blenders.

Some operators require two blenders to be onsite and powered at all times. In such a case, one blender can be prioritized for load shedding over the other. There are also designs to manufacture a blender that does not require an auxiliary unit.
(44) The load shedding control system of the present technology also works independently of the placement of the VFDs or transformers. They can be individual skids/trailers or they can be included onboard the pump trailers or blenders. In addition, in certain embodiments, the system of the present technology can work on electrically powered equipment that is skid mounted, trailer mounted, or bodyload mounted.
(45) The load management control system can work for any commonly used voltage due to its ability to control the electrical breakers and/or the onboard controls for the equipment. This includes the power distribution methods of constant voltage where the voltage generated is also the voltage utilized by the equipment, a step up voltage transformer where the voltage that is generated is stepped up to a higher voltage for use by the equipment, and the use of step down voltage transformers where the voltage generated is stepped down to be utilized by the equipment.
(46) There are also some designs that require a 1:1 voltage transformer where the voltage is not changed, but is used to isolate the equipment from what is sometimes called “dirty power,” where harmonics or ripples can affect the quality of the power supply, and an isolation transformer can be used to prevent damage to the equipment. Common voltages used are 13.8 kV, 4,160V, 700 V, 600V, and 480V.
(47) In some embodiments, different oilfield equipment may require different voltages. Possibly, the fracturing equipment can require 600V, but a drilling rig can require 480V. It is even possible that different types of electrically powered frac equipment can be used where some frac pumps require 600V and others require 4,160V. In such situations, the use of step down or step up transformers can be provided. These transformers can be installed onboard the pump trailers, or can be separate pieces of equipment with interconnecting electrical cables.
(48) According to some embodiments of the present technology, the microgrid can safely and reliably provide power to a utility grid or third party power grid (e.g., for other oilfield or industrial processes), or to supplement from it to a certain amount of power. If the electrical draw from the microgrid becomes too large for the utility grid to handle, the tie breaker can be opened to isolate the grids to prevent a black out of the utility. The opposite is also true. If the utility is drawing too much power from the microgrid, it can be “shed.” These parameters can be set in the software prior to energizing equipment and connecting external utility grids.
(49) In other words, embodiments of the present technology provide for limited tie breaker load sharing or full tie breaker load sharing. Limited tie breaker load sharing can open the breaker when an allowable power draw is exceeded, such as for an external power grid or non-critical process. Full tie breaker load sharing can be used for common processes such as frac equipment that requires multiple switchgear to electrically connect everything. In this case, no limits can be imposed on the tie breaker (other than for safety so breakers or power cables don't fail) and the load management system can shed load or add generators as needed while keeping the tie breaker between switch gears closed to allow load sharing.
(50) Often times smaller diesel generators only operate at 480V or 600V. If one of these is used as a DBU, a step up transformer may be required to allow it to be electrically connected to the microgrid. There may also be situations where step down transformers will be required to voltage match generators so they can be tied to a common bus. This is also true for when a utility grid is being electrically connected to the microgrid. Utilities often operate at different voltages and can be stepped up or stepped down, or possibly require the use of an isolation transformer.
(51) This load shedding control system of the present technology can be used with or without switch gear tie breakers. The load management software can prevent blackouts even it if has to treat each switch gear as an isolated circuit.
(52) According to some embodiments, each incoming generator connection to a switch gear can be

a diesel or natural gas powered turbine engine or reciprocating engine. The power output capacity is inconsequential as well. Smaller diesel or natural gas generators can be as little as 400 kW or as large at 2000 kW. Larger generators (usually turbines) can be from 3,000 kW all the way up to 30,000 kW, and in some cases even larger.

(53) Referring now to FIG. **4**, there is shown a system **400** incorporating most of the features described above in a single microgrid. Thus, FIG. **4** illustrates the capabilities of oilfield power generation with a mobile microgrid outfitted with a load management software control package. For example, FIG. **4** includes a power generation section **402** includes five turbine generators **404**A-E and a diesel backup generator **405**. Different types of generators may be arranged at the well site and produce different quantities of electrical energy. Furthermore, different sizes of generators may be utilized in order to accommodate size and space restrictions at the well site. It should be appreciated that other equipment, such as compressors, filters, heaters, electronic equipment rooms and the like can be part of the system, but have been omitted from the figures for clarity.

(54) The illustrated embodiment further includes a power distribution section **406** including switch gear units **408**A-C for protection and distribution, as well as auxiliary unit **410**. As shown, the generators **404**A-E produce electrical energy for transmission to the switch gear units **408**A-C. Thereafter, step down transformers can receive and convert the energy to to a different voltage, as needed, and the energy is then distributed to pumps **412**. As shown, the auxiliary unit **410** can be utilized to step down the energy for the associated fracturing equipment, such as a data van **414**, blender **416**, sand equipment **418**, and a hydration unit **420**. In various embodiments, the auxiliary unit(s) **410** may include transformers to step down the energy as required.

(55) Continuing with FIG. **4**, the illustrated embodiment includes hydraulic fracturing equipment, such as the illustrated pumps **412**, data van **414**, blenders **416**, sand equipment **418**, and hydration unit **420**. It should be appreciated that various components have been simplified and/or removed for clarity. Moreover, the embodiment illustrated in FIG. **4** is not intended to be limiting. For instance, more than **10** frac pumps may be arranged at a well site. Moreover, multiple data vans, blenders, sand equipment, and hydration units may be utilized. The illustrated pumps **412** can be twin frac pumps. The twin frac pumps may be arranged on a common skid or trailer and receive energy from the transformers. It should be appreciated that the pumps **412** may be configured to operate at different voltages. Moreover, in embodiments the pumps **412** may be singular pumps mounted on a trailer or skid with or without an integrated transformer.

(56) The system of FIG. **4** includes step up transformers for power generation, step down transformers **409** (discussed above) for power generation, a diesel backup generator **405** electrically connected to the bus (switch gear system), natural gas reciprocating generators **436** electrically connected to the bus, natural gas turbine generators **404**A-D electrically connected to the bus, turbine generators having different voltage outputs, switch gear tie breakers **422**, a tie breaker to a local utility grid with a transformer **438** if needed (transformer **438** can be step up, step down, or isolation, according to the requirements of the system). The system can also include the ability to supply power to a non-fracturing application at a different voltage (e.g., the drilling rig at 480V), step down transformers **409** for equipment, as well as step up and step down transformers **434** for voltage matching the power distribution switch gear.

(57) The use of different types of generators allows for constant voltage (e.g., 4,160V power generation supplying 4,160V frac equipment), step down voltage (4,160V and 13.8 kV generators supplying power to the common bus which is being stepped down to power 600V frac equipment and 480V drilling equipment, and even the 13.8 kV being stepped down to 4,160V), and step up voltage (e.g., 480V generators on the same common bus providing power for the 600V and 4,160V frac equipment). This arrangement allows for frac equipment of different operating voltages pumping on a common well, or even on different wells.

(58) In the embodiment shown in FIG. **4**, the diesel generator can be used as prime power or as a

diesel backup generator. Similarly, any electrically connected generator can be used for prime power or standby (back-up) power. Furthermore, any standby generator can be managed by the load shedding software of the present technology to automatically start and connect to the bus if total power load is approaching the maximum power generation of the prime power generators. Power loads can be shed individually but shutting down specific frac pumps, or power load can be shed in groups by opening up tie breakers in extreme power loss situations.

(59) The present disclosure described herein, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as others inherent therein. While presently preferred embodiments of the disclosure have been given for purposes of disclosure, numerous changes exist in the details of procedures for accomplishing the desired results. These and other similar modifications will readily suggest themselves to those skilled in the art, and are intended to be encompassed within the spirit of the present disclosure disclosed herein and the scope of the appended claims.

Claims

1. A system for completing a well, the system comprising: two or more generators; a plurality of electric load components, each electric load component powered by the two or more generators; and a load shedding control panel that monitors the two or more generators and, if at least one of the two or more generators loses functionality, the load shedding control panel deactivates one or more of the plurality of electric load components to reduce an electric load, wherein the load shedding control panel prioritizes an order in which at least one or more of the plurality of electric load components are deactivated, wherein the plurality of electric load components comprises at least one of an electric drilling rig, one or more hydraulic fracturing pumps, a blender, sand equipment, a hydration unit, a data van, or combinations thereof, and wherein deactivation of at least one of the blender, the one or more hydraulic fracturing pumps, the sand equipment, the hydration unit, the data van, and/or combinations thereof prevents deactivation of another one of the blender, the one or more hydraulic fracturing pumps, the sand equipment the hydration unit, the data van, and/or combination thereof in response to reduction of the electric load.
2. The system of claim 1, wherein the one or more generators comprise a natural gas turbine generator, a natural gas generator, a diesel generator, or combinations thereof.
3. The system of claim 1, wherein the load shedding control panel prioritizes the order in which at least one of the blender, the one or more hydraulic fracturing pumps, the sand equipment, the hydration unit, the data van, and/or combinations thereof are deactivated prior to deactivation of the electric drilling rig.
4. The system of claim 1, wherein deactivation of at least one of the blender, the one or more hydraulic fracturing pumps, the sand equipment, the hydration unit, the data van, and/or combinations thereof prevents deactivation of the electric drilling rig in response to reduction of the electric load.