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- (54) **OPTIMIZED LOCAL POWER SYSTEMS**
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- (*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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See application file for complete search history.

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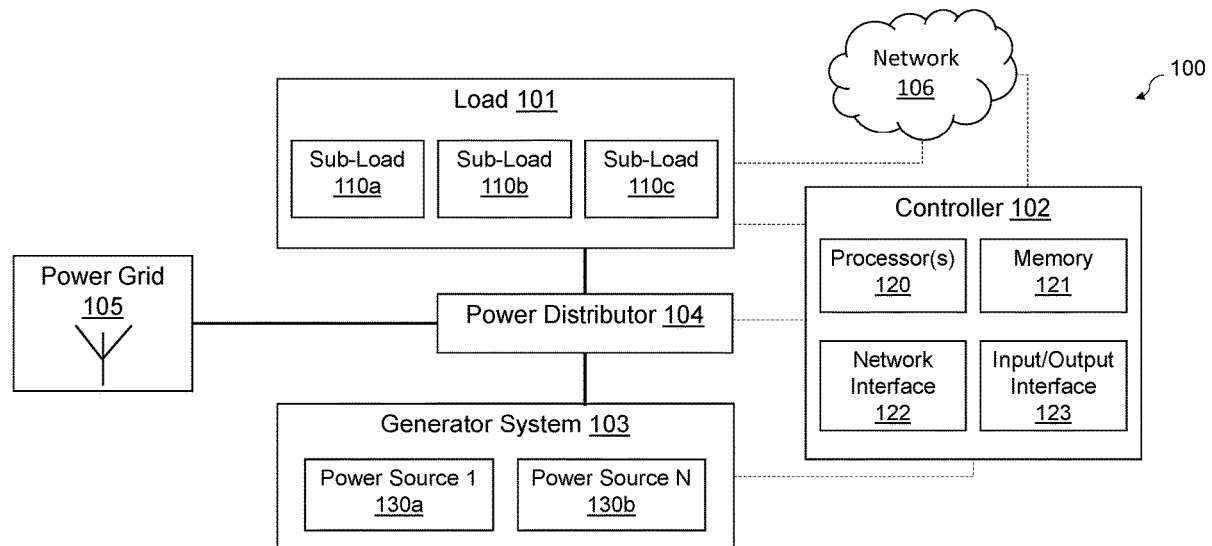
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(57) **ABSTRACT**

In one embodiment, the disclosed technology involves a system having a generator set comprising a first engine and an output terminal coupled to a power distributor, a load comprising two or more sub-loads, wherein each of the sub-loads are coupled to the power distributor via one or more respective electrical contactors, and a controller communicably coupled to the electrical contactors and the generator set comprising a processor, and a memory, the memory having computer-readable instructions stored thereon that, when executed by the processor cause operations. The operations may include determining a number of sub-loads available, receiving data representing power generation of the generator set, determining which of the available sub-loads to connect in order to balance the generator set to the load, and controlling the respective electrical contactors of the determined sub-loads so as to provide electricity to the determined sub-loads.

19 Claims, 6 Drawing Sheets



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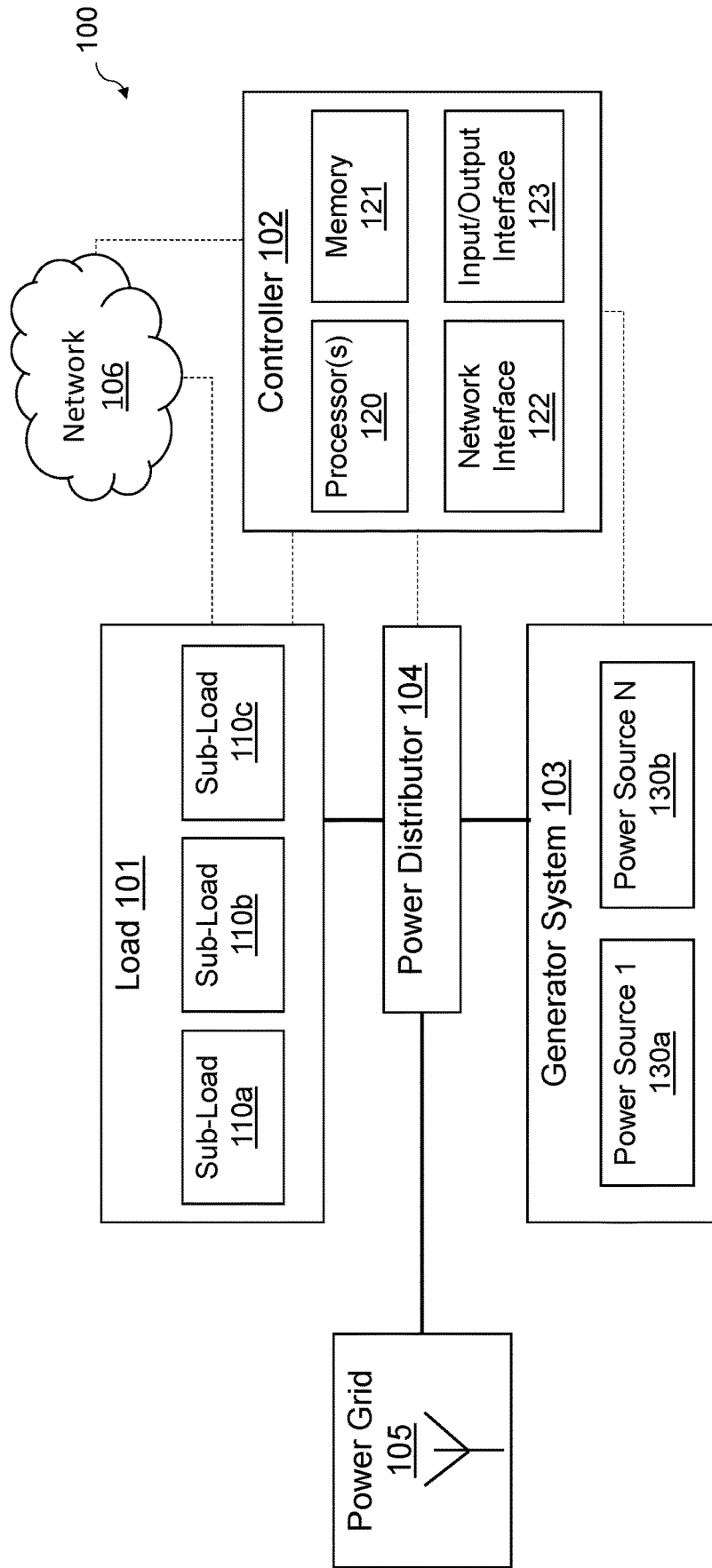


FIG. 1

200

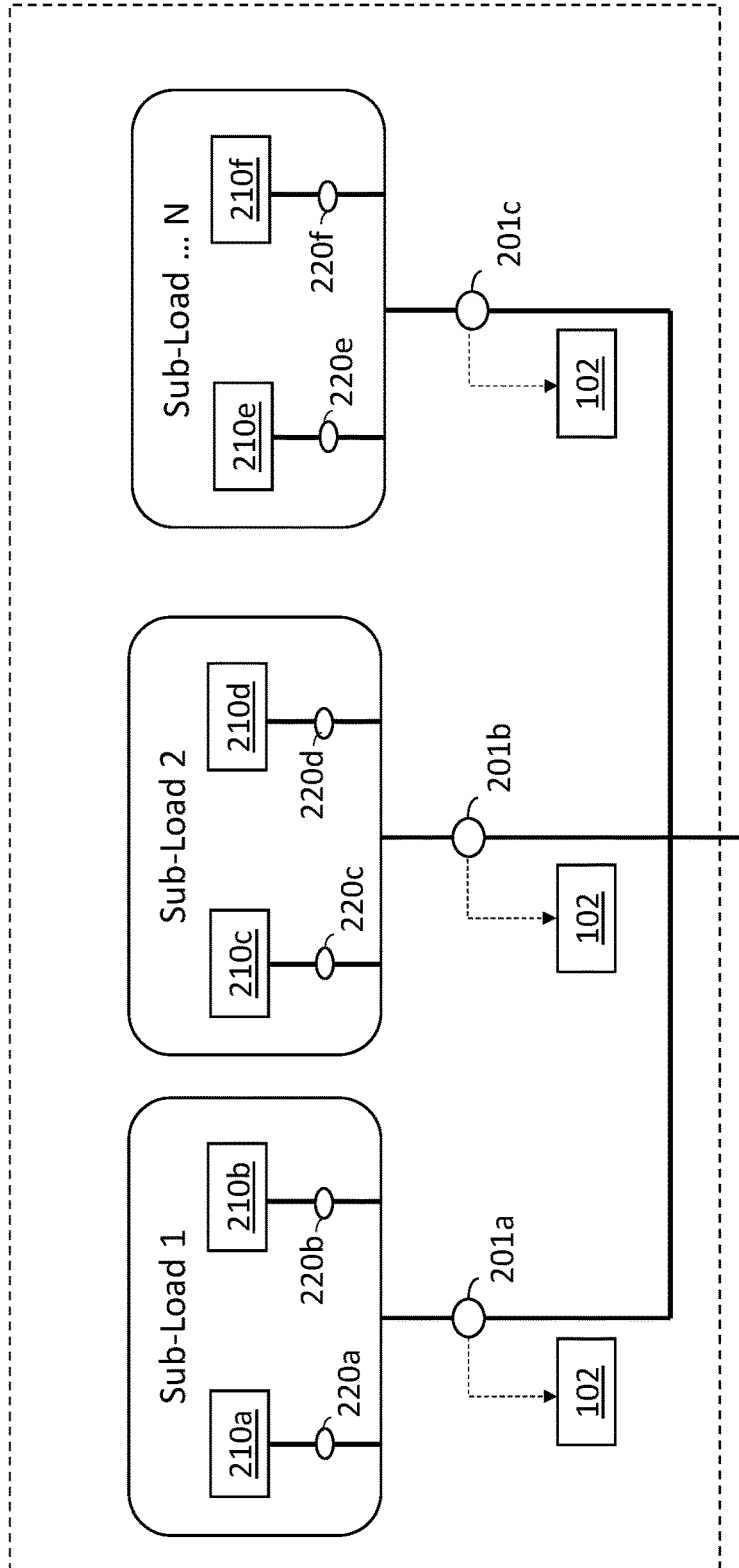


FIG. 2

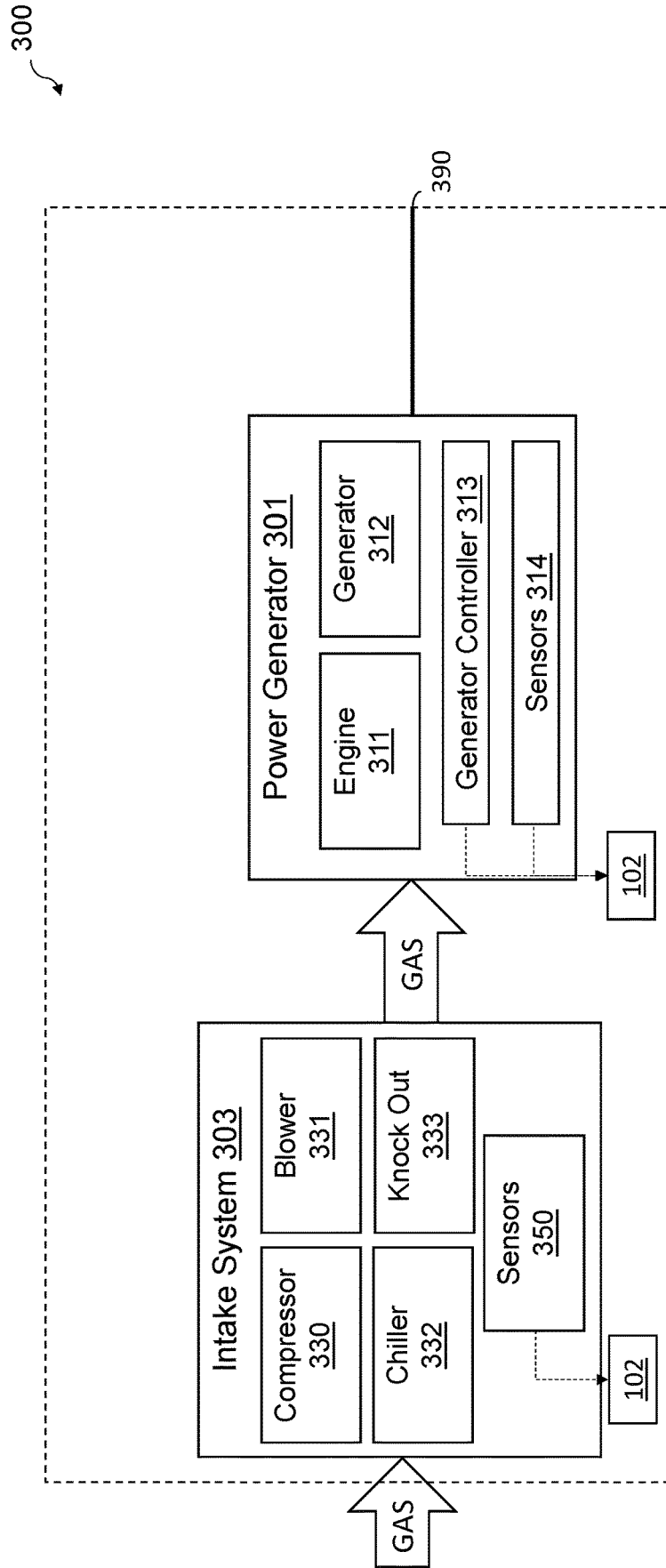


FIG. 3

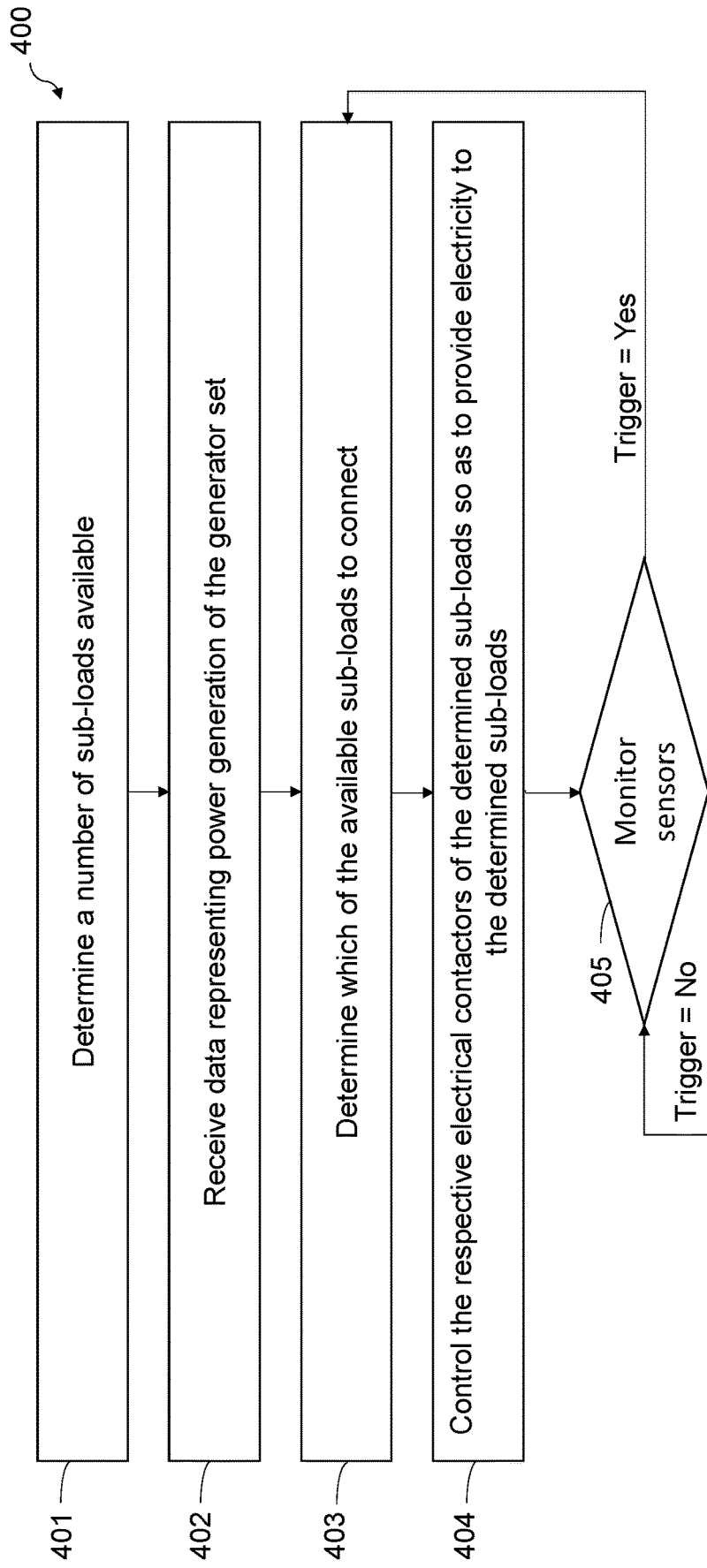


FIG. 4

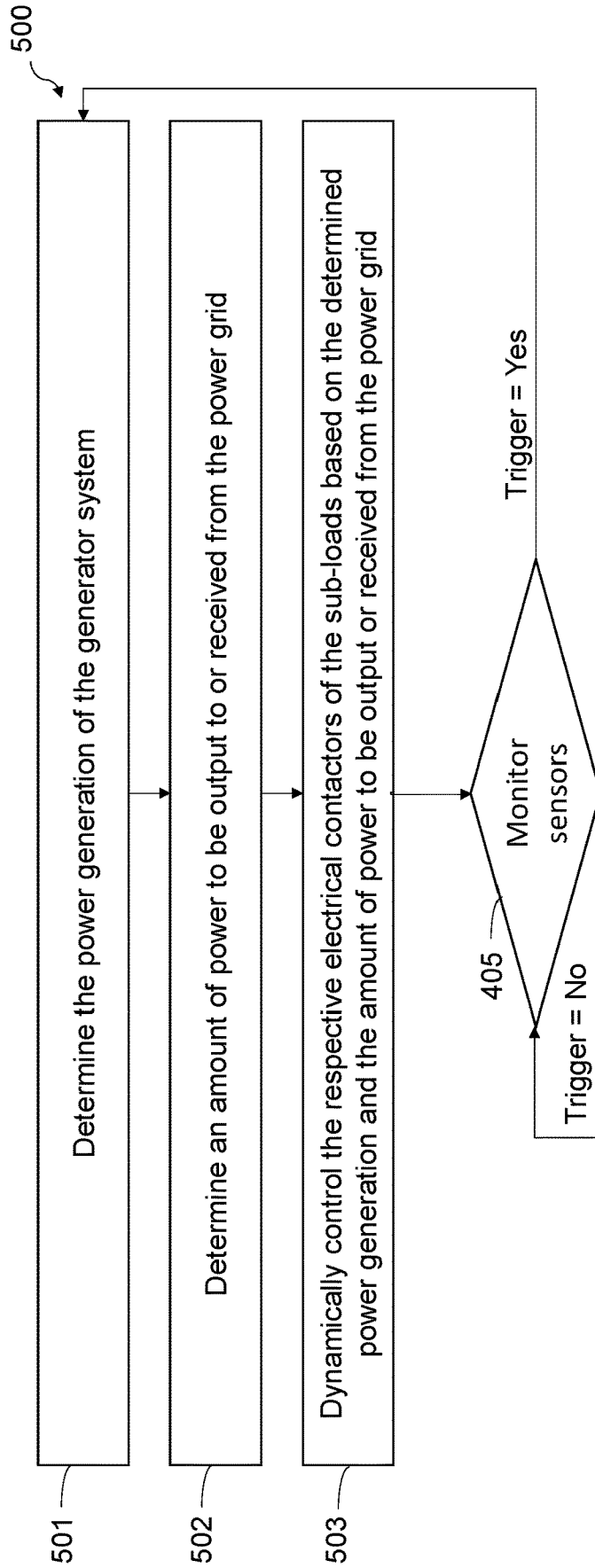


FIG. 5

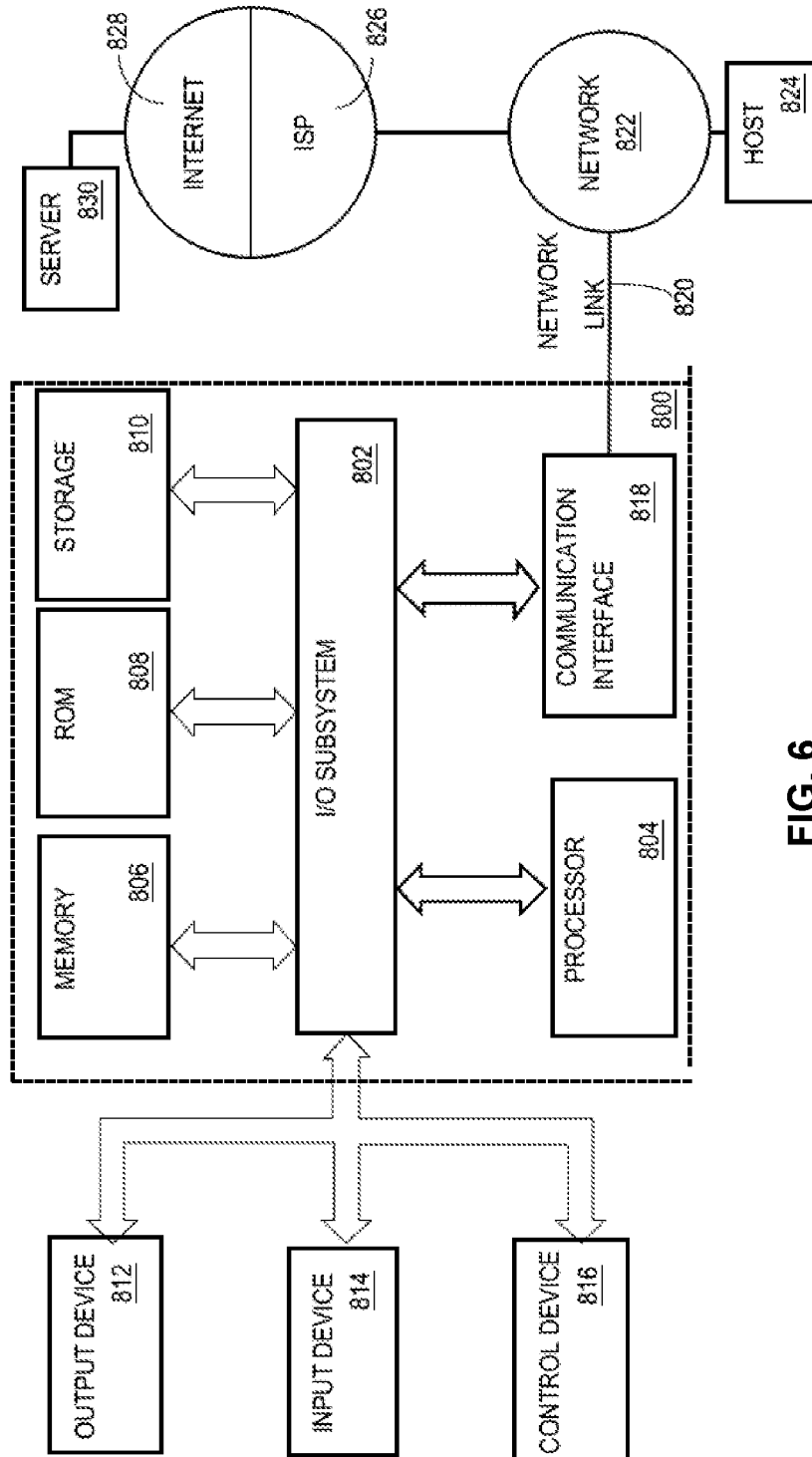


FIG. 6

OPTIMIZED LOCAL POWER SYSTEMS**BENEFIT CLAIM**

This application claims the benefit under 35 U.S.C. § 119(e) of provisional patent application 63/493, 582, filed Mar. 31, 2023, the entire contents of which are hereby incorporated by reference as if fully set forth herein. Applicant hereby rescinds any disclaimer of claim scope in the application(s) of which the benefit is claimed and advises the USPTO that the present claims may be broader than any application(s) of which the benefit is claimed.

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TECHNICAL FIELD

One technical field of the disclosure is systems and methods for powering and operating a data center, such as a landfill gas-powered or biogas-powered data center. Another technical field is control systems for methane gas-powered or biogas-powered thermomechanical systems. Another technical field is systems and methods for controlling a localized system having a generator system and a data center that are selectively coupled to a power grid and the harmonization of each. Another technical field is systems and methods for power generation, including systems and methods for power generation for harmonization with other grid-connected systems.

BACKGROUND

The approaches described in this section are approaches that could be pursued, but not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section.

Power generation centers may lack the ability to be responsive to changes or transient changes in loads or power generation on the grid. Moreover, renewable energy sources such as wind, solar, or biogas-fueled generators may be dependent on the weather and/or related pressure systems within the environment in which they operate. As a result, this may cause additional transients or volatility that need to be accounted for to maintain grid stability. Moreover, even renewable resource power sources that are operating in isolation for example, not connected to a power grid—suffer from the same volatile electrical power output that prevents an efficient usage of the generated energy.

In the case of biogas-fueled generators, landfills may serve as the energy source. Landfills are used to dispose of waste, including large amounts of organic matter, which may be buried under layers of soil to facilitate decomposition. Landfills are often located far from inhabited areas, sometimes by law or regulation; thus, landfill operators may not have convenient access to the types of infrastructure commonly found in more populated areas.

In landfills, microorganisms acting on organic matter under anaerobic conditions produce biogas, which is also known as landfill gas. Landfill gas typically comprises a mixture of methane, carbon dioxide, and other trace gases and vapors. A large percentage of the available energy of the organic matter may be retained in biogas as methane. Thus, methane-rich biogas may have a high calorific value and can be used as a fuel. However, there are several technical challenges associated with using landfill gas as a fuel.

For example, there are certain challenges associated with variabilities inherent in landfill gas and landfills generally. Biogas pressure may be irregular, varying over time with local environmental and seasonal conditions. Additionally, pressure and other characteristics of landfill gas may be affected by the heterogenous and variable composition of the organic constituents of a given landfill from which the biogas arises. These issues may affect the reliability or the consistency of generators that use the biogas to generate electricity.

Hence, natural gas wells may be stranded or underutilized due to technical challenges associated with landfill gas. Indeed, millions of dekatherms of biogas and natural gas are either flared or vented at landfills and oil or gas basins every year. If a technical solution could be developed to effectively address the aforementioned technical issues, it would represent a significant advance in the state of the art.

SUMMARY

The appended claims may serve as a summary of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 illustrates the context of use and principal functional elements with which one embodiment of the disclosed technology could be implemented.

FIG. 2 illustrates a data center with which one embodiment of the disclosed technology could be implemented.

FIG. 3 illustrates a generator system with which one embodiment of the disclosed technology could be implemented.

FIG. 4 illustrates a first method of operating the principal functional elements of the system by which one embodiment of the disclosed technology could be implemented.

FIG. 5 illustrates a second method of operating the principal functional elements of the system which one embodiment of the disclosed technology could be implemented.

FIG. 6 illustrates a second method of operating the principal functional elements of the system which one embodiment of the disclosed technology could be implemented.

DETAILED DESCRIPTION

In the following description, for the purposes of explanation, numerous specific details are set forth to provide a thorough understanding of the present invention. It will be apparent, however, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form to avoid unnecessarily obscuring the present invention.

The text of this disclosure, in combination with the drawing figures, is intended to describe in prose various embodiments of the disclosed technology, at the same level

of detail that is used by people of skill in the arts to which this disclosure pertains to communicate with one another. That is, the level of detail set forth in this disclosure is the same level of detail that persons of skill in the art normally use to communicate with one another to implement the inventions claimed herein.

Embodiments are described in sections below according to the following outline:

1. General Overview
2. Structural Overview
3. Functional Overview
4. Benefits and Improvements

1. General Overview

In one embodiment, the disclosed technology involves a system having a generator set comprising a first engine and an output terminal coupled to a power distributor, a load comprising two or more sub-loads, wherein each of the sub-loads is coupled to the power distributor via one or more respective electrical contactors, and a controller communicably coupled to the electrical contactors and the generator set comprising a processor and a memory—the memory having computer-readable instructions stored thereon that, when executed by the processor, cause operations. The operations may include determining several sub-loads available, receiving data representing power generation of the generator set, determining which of the available sub-loads to connect to balance the generator set to the load, and controlling the respective electrical contactors of the determined sub-loads to provide electricity to the determined sub-loads.

2. Structural Overview

FIG. 1 illustrates the context of use and principal functional elements with which one embodiment of the disclosed technology could be implemented. FIG. 1 illustrates only one of many possible arrangements of components configured to execute the functions described herein. Other arrangements may include fewer or different components, and the order of the components may be different in other embodiments. Electro-mechanical components for electrical connections, power distribution, and sensor arrangements may differ. Moreover, in various embodiments, one or more sets of system components may be combined into one or more respective integral units or mounted together on one or more modular units.

In one embodiment, a system **100** includes a load **101**, a controller **102**, a generator system **103** (e.g., a generator set, a bio-gas fueled power generator, etc.), and a power distributor **104**. In an embodiment, the load **101** includes one or more sub-loads **110a-c** that are selectively coupled to a power source via the controller **102**. For example, the load **101** may include a data center and the sub-loads **110a-c** may be compartmentalized portions of the data center that are selectively coupled to power based on one or more conditions determined by the controller **102**. FIG. 2 illustrates a data center **200** with which one embodiment of the disclosed technology could be implemented. In some embodiments, the load **101** may be comprised of a data center and other load devices as described herein. In an embodiment, the system **100** may be considered a grid-connected system when the system **100** is coupled to a power grid, for example, via one or more substations of the power grid.

In some embodiments, the power distributor **104** may be connected to a power grid **105** such as a utility grid, a

micro-grid, a local multiutility grid, and so on. The power grid **105** may be managed by a grid operator that is affiliated with a different entity. For example, the grid operator may be a manager that ensures the reliable delivery of electricity to consumers, businesses, and industries interconnected to the power grid **105**. In some embodiments, the grid operator may have one or more computer devices connected to the network **106** that monitor the status of the power grid and communicate with the computer devices of nodes connected to or configured to be connected to the power grid **105** via the network **106**. In one example, the computer devices of the grid operator may communicate with the controller **102**.

2.1 Load

As discussed above, the load **101** may include various types of loads such as computers, industrial or commercial equipment, charging stations, storage devices, or the like. In an embodiment, the load **101** includes a data center **200** as illustrated in FIG. 2. In various embodiments, data center **200** may accommodate a combination of computing devices and infrastructure, including, racks, servers, storage devices, networking apparatus, power supplies, batteries or other backup power equipment, cooling equipment, fire suppression or other safety equipment, security or access equipment, and the like. In one embodiment, one or more separate support containers that house cooling equipment or other infrastructure may also be deployed alongside the data center **200**. In one embodiment, network connectivity is built into the data center **200**.

In an embodiment, data center **200** operates on network **106**. Network **106** broadly represents any combination of one or more data communication networks (including local area networks, wide area networks, internetworks, or internets) using any wireline or wireless links, including terrestrial or satellite links. The network(s) may be implemented by any medium or mechanism that provides for the exchange of data between the various elements of the data center **200** and controller **102** as described herein. In an embodiment, the data center **200** includes one or more containerized data centers.

The data center **200** may be portioned out into various sub-loads **202a-n** that are configured to be connected to power via respective electrical contactors **201a-n**. For example, the electrical contactors **201a-n** may be communicably coupled to the controller **102** such that the controller **102** can operate the electrical contactors **201a-b** individually to selectively couple the respective sub-load **202a-n** to electrical power. In an embodiment, the electrical contactors **201a-d** include a control connection (e.g., terminals) coupled to the controller **102**, an input terminal(s) connected (indirectly or directly) to a power source (e.g., directly or indirectly to the output terminals of the generator system **103**), and an output terminal(s) connected to an input terminal(s) of the respective sub-load. As one example, the electrical contactor **201a** may include a Sunlee controls 3 pole 220-volt (V) 240V coil 60-amp contactor or the like.

In some embodiments, the sub-loads **202a-n** may include portions of the data center **200** that are partitioned based on the load size of the sub-loads **202a-n**. For example, each sub-load **202a-n** may correspond to a 50 kilowatt (kW) electrical load. As another example, each sub-load **202a-n** may have a corresponding electrical load unique to each sub-load that is determined by or programmed into the controller **102**. In this way, the controller **102** may be able to dynamically determine the operations necessary to bring each sub-load **202a-n** online to maximize the load without overloading the system. Similarly, the controller **102** may be able to dynamically determine the operations necessary to

turn off portions of the data center **200** while maximizing the efficiency of the generator system **103**.

The various elements of data center **200** may also have direct (wired or wireless) communications links. The computers of data center **200**, computing devices, and other communicatively coupled system elements may each comprise an interface compatible with the network **106** and may be programmed or configured to use standardized protocols for communication across the networks such as TCP/IP, Bluetooth, or higher-layer protocols such as HTTP, TLS, and the like. Moreover, the devices of the data center **200**, such as the electrical contactors, breakers, fuses, and sensors associated therewith may be communicably coupled to the controller **102**, which may be able to monitor or control.

In some embodiments, one or more of the sub-loads may include one or more computing devices **210a-210f** being programmed to execute at least one of: hosting a distributed ledger, mining a cryptocurrency, staking the cryptocurrency, or validating the cryptocurrency, or hosting a cloud computing application. In various embodiments, the computing devices **210a-210f** of data center **200** may execute programmed instructions formatted to cause the execution of transactions on the ETHEREUM, BITCOIN, or BITCOIN CASH blockchains, or on another blockchain, public or private. In embodiments, the computing devices **210a-210f** of data center **200** execute programmed instructions formatted to cause the mining of a cryptocurrency such as ETHEREUM (ETH), BITCOIN (BTC), BITCOIN CASH (BCH), CARDANO (ADA), BINANCE COIN (BNB), LITECOIN (LTC), TETHER (USDT), SOLANA (SOL), DOGECOIN (DOGE), POLKADOT (DOT), USD (USDC), or another cryptocurrency or crypto token

Additionally or alternatively, one or more of the sub-loads may also include one or more cooling devices (e.g., cooling fans, liquid cooling system, etc.) that are configured to cool the respective computing devices **210a-210f** or other load devices.

In an embodiment, the computing devices **210a-210f** being programmed for mining a cryptocurrency or executing transactions on a blockchain has several technical advantages. One technical advantage is that the load presented to the biogas-fueled power generator **301**, albeit variable, may be relatively predictable and scalable/adjustable. Moreover, the sub-loads allow for the system to selectively activate (e.g., connect to power) different portions of the data center based on a forecasted power output by the generator, which ensures that the load is efficiently balanced not only with the generator system but also the power grid, if needed.

Another technical advantage is that sub-loads **202a-n** configured to execute operations on a blockchain allow for the controller **102** to dynamically connect and disconnect power to various sub-loads nearly instantaneously without concern of whether data will be lost. For example, because blockchain transactions may occur on a publicly accessible, immutable ledger, after the sub-load is re-connected to the power source, the computing devices of the data center **200** may be programmed to easily resume operations with no loss of critical data. These are important advantages because renewable energy is inherently volatile, and conditions may change quickly, thus the amount of power supplied or capable of being supplied to the data center **200** may be relatively volatile or irregular. Thus, having a unique structure to the data center **200** allows for the controller **102** to dynamically balance power loads based on the available energy and, in some embodiments, accommodate requests from the grid operator to ensure stabilization and harmoni-

zation both within the internal system and on the utility grid without the risk of losing critical data, which is discussed in additional detail below.

In some embodiments, the ability to dynamically control the load **101** (e.g., the data center **200**) via the electrical contactors **201a-d** allows for the controller **102** to be able to balance the load efficiently and effectively with the output power of the generator system **103**, thereby reducing the possibility of needing to flare off methane gas, which improves the sustainability of both the system and climate. In various embodiments, the sub-loads **110a-110c** may include the portions of the data center **200** and other loads such as battery storage devices, battery charging devices such as electric vehicle chargers, or other types of electrical loads. For example, in some embodiments, the sub-loads **110a-110c** may include battery storage systems that the controller **102** is able to selectively couple to the power source when there is excess energy being generated.

2.2 Generator System

The generator system **103** is communicably coupled to the controller **102** in a manner that allows for the controller **102** to monitor the generator system **103**. For example, the generator system **103** may include various output terminals and/or a local processor (e.g., a microprocessor, application-specific integrated circuit, etc.) that is communicably coupled (e.g., via wired or wireless communication) to the controller **102** such that the controller **102** can monitor a status of the generator system **103**. In some embodiments, the controller **102** may receive data that indicates the anticipated electrical power output of the generator system **103**, for example, in an upcoming period. The upcoming period may be 1 minute, 2 minutes, 5 minutes, 5-45 minutes and so on. In some embodiments, the generator system **103** may have various sensors configured to measure inputs to the generator system **103** that can be used, either by the generator system **103** or controller **102**, to calculate the anticipated power output of the generator system **103**. In other embodiments, the generator system **103** and/or controller **102** may also receive information via the network **106** to receive data regarding environmental conditions such as weather forecasts to also calculate or determine the anticipated power output of the generator system **103**.

The generator system **103** includes at least one power source **130a-130b**. In some embodiments, the power source may include one or more of a low British thermal unit (Btu) gas engine, biogas engine, nuclear reactor, natural gas engine, geothermal system, solar system, solar system with batteries, wind turbines, hydrogen system (e.g., hydrogen fuel cells) compressed air, or another source that can be dispatchable through inputs of fuel (or environmental commodity such as wind) to drive a prime mover for the generation of electricity. FIG. 3 illustrates a generator system **300** with which one embodiment of the disclosed technology could be implemented. The generator system **300** of FIG. 3 includes one or more biogas engines and generators as power sources that are configured to receive biogas (e.g., gas produced from a landfill) and output electricity. However, as noted above, in other embodiments, the power source(s) may include a variety, or combination, of power sources **130a-130b**.

The generator system **300** includes a biogas-fueled power generator **301** and an intake system **303**. The biogas-fueled power generator **301** includes an engine **311** structured to receive biogas as an input to generate torque to power a first generator **312** (e.g., a first mover) to output electrical power. The biogas-fueled power generator **301** and the intake system **303** include a variety of sensors that are configured

to sense a condition and output an electrical signal representative of the sensed condition. The electrical signal is then sent to the controller **102** for further processing as discussed in further detail below. In various embodiments, the generator system **300** may include two or more biogas power generators.

In an embodiment, the biogas-fueled power generator **301** includes one or more terminals that are communicably coupled to the controller **102** via wired or wireless connections. As an example, the biogas-fueled power generator **301** may include a plurality of terminals that are wired to respective terminals of the controller **102** that output respective electrical signals to indicate the status of the biogas-fueled power generator **301**. For example, the electrical signals may be generated via sensors **314** and/or the generator controller **313**. The signals may include a status of one or more emergency devices or buttons (e.g., triggered or cleared), a fault condition of the generator, a run status of the generator, a fault condition of one or more devices of the generator, an electrical trip of the generator, a gas analyzer fault of the generator, an HH level of the generator, a LL level of the generator, or other conditions associated with the operation of the engine of the generator.

The intake system **303** may include a blower skid. The blower skid is structured to receive gas coming in (e.g., from a source such as a landfill), knock out the moisture of the gas via one or more vessels in a knockout system **333**, compress the gas via a compressor **330**, cool the gas via an aftercooler or chiller **332**, and output the gas into an intake of the biogas-fueled engine of the power generator **301** via a blower **331**. In this example, the intake system **303** includes various sensors **350** that are configured to measure a condition of the intake system **303** and output an electrical signal representing the respective condition to the controller **102** for further processing. The various sensors **350** may output the electrical signal representing the condition directly to the controller **102** or may output the electrical signal to a local computer processor (e.g., a microprocessor, application specific integrated circuit, etc.) that serves as an intermediary between the sensors **350** and the controller **102**.

As one example, the intake system **303** may include one or more sensors or devices **350** that output an electrical signal representative of a speed of the blower, a speed of the after cooler, the blower suction temperature, blower discharge temperature (e.g., temperature of the gas being output to the engine), NDE temperature, blower temperature, vibration of the skid, blower skid discharge temperature, blower suction press, discharge pressure, discharge flow, recycle valve position, after cooler fan speed, and so on. In various embodiments, the intake system **303** may also include one or more gas analyzer devices that are configured to output an electrical signal that indicates an amount of methane within the gas and an amount of oxygen within the gas to the controller **102** either directly or indirectly. All of these or a combination of these outputs, such as the amount of methane within the gas, the flow speed of the gas, and/or the amount of oxygen within the gas may be used by the controller **102** to calculate an anticipated amount of power that the generator will be able to output in a particular upcoming period. Additionally or alternatively, the controller **102** may send feedback to the intake system **303** to change operations to either maximize or optimize the devices of the intake system **303** to output an optimized power level based on the received data.

The power generator **301** may have a plurality of electric power output terminals **390** through which electricity may

flow to the load **101** either directly or indirectly via the power distributor. In some embodiments, the plurality of electric power output terminals **390** may include sensors that are structured to measure the current, voltage, and/or electrical power output of the generator **301** and signal the data to the controller **102**. In one embodiment, the load **101** is electrically coupled to the plurality of electric power output terminals **390** via an electrical coupling comprising three-phase delta wiring and through a three-phase electrical panel. The power distributor **104** may intermediate the interconnection of the load **101** (e.g., data center **200**) with the output terminals **390** of the biogas-fueled power generator **301** by regulating an amperage and voltage drawn through the three-phase delta wiring. The biogas-fueled power generator **301** may have an internal computer (e.g., a microprocessor, application-specific integrated circuit, etc.) **313** that regulates current and/or voltage output. In one embodiment, no neutral is needed for powering the data center **200** because the load **101** is stable. In other embodiments, Wye wiring may be used instead.

In one embodiment, the biogas-fueled power generator **110** is configured to operate at 60 Hz and 480V and to provide a power output in a range of 800 to 2500 kVA. One known commercial example of a biogas-fueled power generator **110** is the G3520C Continuous Low Energy Gas Generator Set manufactured by CATERPILLAR INC. of Deerfield Illinois, but many others are possible. In various embodiments, the biogas-fueled power generator **301** does not comprise a catalytic converter.

In one embodiment, the biogas-fueled power generator **301** is configured to operate at 480V or more and is electrically connected to a transformer that steps down the operating voltage to 240V. In some embodiments, the transformer may be part of the generator system **103** or the power distributor.

2.3 Controller

The controller **102** may include one or more processors **120**, a memory device **121**, a network interface **122**, and an input/output interface **123**. In some embodiments, the input/output interface **123** may have one or more terminals structured to be wired to the various sensors and devices of the generator system **103** and the load **101** to monitor the status thereof. Additionally or alternatively, the controller **102** may include one or more terminals structured to electrically and mechanically couple to the electrical contactors **201a-n** of the sub-loads to monitor the status of the electrical contactors and/or individually control each of the electrical contactors.

The one or more processors **120** can include a microprocessor, programmable logic controller (PLC) chip, an ASIC chip, or any other suitable processor. The one or more processors **120** may take the form of a single core processor, multi-core processor (e.g., a dual core processor, triple core processor, quad core processor, etc.), etc. In some embodiments, the one or more processors **120** may be external to the system, for example the one or more processors **120** may include a remote processor (e.g., a cloud-based processor). Alternatively or additionally, the one or more processors may be internal and/or local to the apparatus. In this regard, a given component of the controller **102** may be disposed locally (e.g., as part of a local server, a local computing system, etc.) or remotely (e.g., as part of a remote server such as a cloud-based server).

The memory device **121** includes any of the memory and/or storage components discussed herein. For example, memory device **121** may include RAM and/or cache of the processor. The memory device **121** may also include one or

more storage devices (e.g., hard drives, flash drives, computer-readable media, etc.) either local or remote to controller **102**. The memory device **121** is structured to store historical data of data received via the network **106**, the generator system **103**, and the load **101**. Moreover, the memory device **121** is structured to store non-transitory computer-readable instructions that, when executed by the one or more processors, cause the controller **102** to perform the various operations described herein. For example, the operations may include monitoring the status of the generator system **103** (e.g., via the received signals), monitoring the status of the load **101**, opening and closing the electrical contactors **201a-d**, calculating or determining the anticipated power output of the generator system **103** based on the monitored or received data, sending/receiving data via the network interface and network **106**, and so on.

The network interface **122** is structured to allow the controller **102** to communicate via network **106**. The network interface **122** may include wired interfaces such as serial interface terminals, ethernet terminals, and so on. In some embodiments, the network interface **122** includes wireless network components such as antennas and/or chips that allow the controller **102** to communicate via the network **106** via a wireless local area network (WLAN), Bluetooth connection, cellular network, or the like. In some embodiments, the network interface **122** is configured to execute one or more application programming interfaces (APIs) to establish network connections with personal devices of administrators, with computing devices of a grid operator, and/or other computing devices connected to the power grid **105**.

In some embodiments, the controller **102** may include one or more displays coupled to the one or more processors. For example, the controller **102** may include a human-machine interface (HMI) such as a touch screen that is configured to display portions of the monitored data, the status of the systems, and/or allow for manual changes to be implemented. Alternatively or additionally, a user may use a personal device such as a cellular device, tablet, personal computer, or the like to remote into the controller **102**. Remoteing into the controller **102** allows the personal device to have access to the information monitored, see the graphical user interfaces generated by the controller **102**, manually give the controller **102** commands, and/or program the controller **102** to perform one or more of the operations described herein.

FIG. **6** illustrates an example implementation of the controller of FIG. **1**. According to one embodiment, the functional techniques described herein are implemented by at least one computing device such as controller **102**. The techniques also may be implemented in whole or in part using a combination of at least one server computer and/or other computing devices coupled using a network, such as a packet data network. The computing devices may be hard-wired to perform the techniques or may include digital electronic devices such as at least one application-specific integrated circuit (ASIC) or field programmable gate array (FPGA) that is persistently programmed to perform the techniques or may include at least one general purpose hardware processor programmed to perform the techniques pursuant to program instructions in firmware, memory, other storage, or a combination. To accomplish the described techniques, such computing devices may combine custom hard-wired logic, ASICs, or FPGAs with custom programming. The computing devices may be server computers, workstations, personal computers, portable computer systems, handheld devices, mobile computing devices, wear-

able devices, body-mounted or implantable devices, smartphones, smart appliances, internetworking devices, autonomous or semi-autonomous devices such as robots or unmanned ground or aerial vehicles, any other electronic device that incorporates hard-wired and/or program logic to implement the described techniques, one or more virtual computing machines or instances in a data center, and/or a network of server computers and/or personal computers.

FIG. **6** is a block diagram that illustrates an example computer system with which an embodiment may be implemented. In the example of FIG. **6**, a computer system **800** and instructions for implementing the disclosed technologies in hardware, software, or a combination of hardware and software, are represented schematically, for example, as boxes and circles, at the same level of detail that is commonly used by persons of ordinary skill in the art to which this disclosure pertains for communicating about computer architecture and computer systems implementations. Elements of the computer system **800** can implement controller **102**.

Computer system **800** includes an input/output (I/O) subsystem **802**, which may include a bus and/or other communication mechanism(s) for communicating information and/or instructions between the components of the computer system **800** over electronic signal paths. The I/O subsystem **802** may include an I/O controller, a memory controller, and at least one I/O port. The electronic signal paths are represented schematically in the drawings, such as lines, unidirectional arrows, or bidirectional arrows.

At least one hardware processor **804** is coupled to I/O subsystem **802** for processing information and instructions. Hardware processor **804** may include, for example, a general-purpose microprocessor or microcontroller and/or a special-purpose microprocessor such as an embedded system or a graphics processing unit (GPU), or a digital signal processor or ARM processor. Processor **804** may comprise an integrated arithmetic logic unit (ALU) or be coupled to a separate ALU.

Computer system **800** includes one or more units of memory **806**, such as a main memory, coupled to I/O subsystem **802** for electronically digitally storing data and instructions to be executed by processor **804**. Memory **806** may include volatile memory such as various forms of random-access memory (RAM) or other dynamic storage device. Memory **806** also may be used for storing temporary variables or other intermediate information during the execution of instructions to be executed by processor **804**. Such instructions, when stored in non-transitory computer-readable storage media accessible to processor **804**, can render computer system **800** into a special-purpose machine customized to perform the operations specified in the instructions.

Computer system **800** includes non-volatile memory such as read-only memory (ROM) **808** or other static storage devices coupled to I/O subsystem **802** for storing information and instructions for processor **804**. The ROM **808** may include various forms of programmable ROM (PROM), such as erasable PROM (EPROM) or electrically erasable PROM (EEPROM). A unit of persistent storage **810** may include various forms of non-volatile RAM (NVRAM), such as FLASH memory, solid-state storage, magnetic disk, or optical disks such as CD-ROM or DVD-ROM and may be coupled to I/O subsystem **802** for storing information and instructions. Storage **810** is an example of a non-transitory computer-readable medium that may be used to store instructions and data which, when executed by the processor

804, cause performing computer-implemented methods to execute the techniques herein.

The instructions in memory **806**, ROM **808**, or storage **810** may comprise one or more instructions organized as modules, methods, objects, functions, routines, or calls. The instructions may be organized as one or more computer programs, operating system services, or application programs, including mobile apps. The instructions may comprise an operating system and/or system software; one or more libraries to support multimedia, programming, or other functions; data protocol instructions or stacks to implement TCP/IP, HTTP, or other communication protocols; file format processing instructions to parse or render files coded using HTML, XML, JPEG, MPEG or PNG; user interface instructions to render or interpret commands for a graphical user interface (GUI), command-line interface or text user interface; application software such as an office suite, internet access applications, design and manufacturing applications, graphics applications, audio applications, software engineering applications, educational applications, games or miscellaneous applications. The instructions may implement a web server, web application server, or web client. The instructions may be organized as a presentation, application, and data storage layer, such as a relational database system using a structured query language (SQL) or no SQL, an object store, a graph database, a flat file system, or other data storage.

Computer system **800** may be coupled via I/O subsystem **802** to at least one output device **812**. In one embodiment, output device **812** is a digital computer display. Examples of a display that may be used in various embodiments include a touchscreen display, a light-emitting diode (LED) display, a liquid crystal display (LCD), or an e-paper display. Computer system **800** may include other type(s) of output devices **812**, alternatively or in addition to a display device. Examples of other output devices **812** include printers, ticket printers, plotters, projectors, sound cards or video cards, speakers, buzzers or piezoelectric devices or other audible devices, lamps or LED or LCD indicators, haptic devices, actuators or servos.

At least one input device **814** is coupled to I/O subsystem **802** for communicating signals, data, command selections, or gestures to processor **804**. Examples of input devices **814** include touch screens, microphones, still and video digital cameras, alphanumeric and other keys, keypads, keyboards, graphics tablets, image scanners, joysticks, clocks, switches, buttons, dials, slides, and/or various types of sensors such as force sensors, motion sensors, heat sensors, accelerometers, gyroscopes, and inertial measurement unit (IMU) sensors and/or various types of transceivers such as wireless, such as cellular or Wi-Fi, radio frequency (RF) or infrared (IR) transceivers and Global Positioning System (GPS) transceivers.

Another type of input device is a control device **816**, which may perform cursor control or other automated control functions such as navigation in a graphical interface on a display screen, alternatively or in addition to input functions. The control device **816** may be a touchpad, a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to processor **804** and for controlling cursor movement on an output device **812**, such as a display. The input device may have at least two degrees of freedom in two axes, a first axis (e.g., x) and a second axis (e.g., y), that allows the device to specify positions in a plane. Another type of input device is a wired, wireless, or optical control device such as a joystick, wand, console, steering wheel, pedal, gearshift mecha-

nism, or other control device. An input device **814** may include a combination of multiple input devices, such as a video camera and a depth sensor.

In another embodiment, computer system **800** may comprise an Internet of Things (IoT) device in which one or more of the output device **812**, input device **814**, and control device **816** are omitted. Or, in such an embodiment, the input device **814** may comprise one or more cameras, motion detectors, thermometers, microphones, seismic detectors, other sensors or detectors, measurement devices or encoders, and the output device **812** may comprise a special-purpose display such as a single-line LED or LCD display, one or more indicators, a display panel, a meter, a valve, a solenoid, an actuator or a servo.

When computer system **800** is a mobile computing device, input device **814** may comprise a global positioning system (GPS) receiver coupled to a GPS module that is capable of triangulating to a plurality of GPS satellites, determining and generating geo-location or position data such as latitude-longitude values for a geophysical location of the computer system **800**. Output device **812** may include hardware, software, firmware, and interfaces for generating position reporting packets, notifications, pulse or heartbeat signals, or other recurring data transmissions that specify a position of the computer system **800**, alone or in combination with other application-specific data, directed toward host computer **824** or server computer **830**.

Computer system **800** may implement the techniques described herein using customized hard-wired logic, at least one ASIC or FPGA, firmware, and/or program instructions or logic which, when loaded and used or executed in combination with the computer system, causes or programs the computer system to operate as a special-purpose machine. According to one embodiment, the techniques herein are performed by computer system **800** in response to processor **804** executing at least one sequence of at least one instruction contained in main memory **806**. Such instructions may be read into main memory **806** from another storage medium, such as storage **810**. Execution of the sequences of instructions contained in main memory **806** causes processor **804** to perform the process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions.

The term "storage media," as used herein, refers to any non-transitory media that store data and/or instructions that cause a machine to operate in a specific fashion. Such storage media may comprise non-volatile media and/or volatile media. Non-volatile media includes, for example, optical or magnetic disks, such as storage **810**. Volatile media includes dynamic memory, such as memory **806**. Common forms of storage media include, for example, a hard disk, solid state drive, flash drive, magnetic data storage medium, any optical or physical data storage medium, memory chip, or the like.

Storage media is distinct but may be used with transmission media. Transmission media participates in transferring information between storage media. For example, transmission media includes coaxial cables, copper wire and fiber optics, and wires comprising a bus of I/O subsystem **802**. Transmission media can also be acoustic or light waves generated during radio-wave and infrared data communications.

Various forms of media may carry at least one sequence of at least one instruction to processor **804** for execution. For example, the instructions may initially be carried on a remote computer's magnetic disk or solid-state drive. The

remote computer can load the instructions into its dynamic memory and send them over a communication link such as a fiber optic, coaxial cable, or telephone line using a modem. A modem or router local to computer system **800** can receive the data on the communication link and convert the data to a format that can be read by computer system **800**. For instance, a receiver such as a radio frequency antenna or an infrared detector can receive the data carried in a wireless or optical signal and appropriate circuitry can provide the data to I/O subsystem **802** such as place the data on a bus. I/O subsystem **802** carries the data to memory **806**, from which processor **804** retrieves and executes the instructions. The instructions received by memory **806** may optionally be stored on storage **810** either before or after execution by processor **804**.

Computer system **800** also includes a communication interface **818** coupled to a bus or I/O subsystem **502**. Communication interface **818** provides a two-way data communication coupling to a network link(s) **820** directly or indirectly connected to at least one communication network, such as a network **822** or a public or private cloud on the Internet. For example, communication interface **818** may be an Ethernet networking interface, integrated-services digital network (ISDN) card, cable modem, satellite modem, or a modem to provide a data communication connection to a corresponding type of communications line, for example, an Ethernet cable or a metal cable of any kind or a fiber-optic line or a telephone line. Network **822** broadly represents a local area network (LAN), wide-area network (WAN), campus network, internetwork, or any combination thereof. Communication interface **818** may comprise a LAN card to provide a data communication connection to a compatible LAN, a cellular radiotelephone interface that is wired to send or receive cellular data according to cellular radiotelephone wireless networking standards, or a satellite radio interface that is wired to send or receive digital data according to satellite wireless networking standards. In any such implementation, communication interface **818** sends and receives electrical, electromagnetic, or optical signals over signal paths that carry digital data streams representing various types of information.

Network link **820** typically provides electrical, electromagnetic, or optical data communication directly or through at least one network to other data devices, using, for example, satellite, cellular, Wi-Fi, or BLUETOOTH technology. For example, network link **820** may connect through network **822** to a host computer **824**.

Furthermore, network link **820** may connect through network **822** or to other computing devices via internet-working devices and/or computers operated by an Internet Service Provider (ISP) **826**. ISP **826** provides data communication services through a worldwide packet data communication network called Internet **828**. A server computer **830** may be coupled to Internet **828**. Server computer **830** broadly represents any computer, data center, virtual machine, or virtual computing instance with or without a hypervisor, or computer executing a containerized program system such as DOCKER or KUBERNETES. Server computer **830** may represent an electronic digital service that is implemented using more than one computer or instance and that is accessed and used by transmitting web services requests, uniform resource locator (URL) strings with parameters in HTTP payloads, API calls, app services calls, or other service calls. Computer system **800** and server computer **830** may form elements of a distributed computing system that includes other computers, a processing cluster, a server farm, or other organizations of computers that

cooperate to perform tasks or execute applications or services. Server computer **830** may comprise one or more instructions organized as modules, methods, objects, functions, routines, or calls. The instructions may be organized as one or more computer programs, operating system services, or application programs, including mobile apps. The instructions may comprise an operating system and/or system software; one or more libraries to support multimedia, programming, or other functions; data protocol instructions or stacks to implement TCP/IP, HTTP, or other communication protocols; file format processing instructions to parse or render files coded using HTML, XML, JPEG, MPEG or PNG; user interface instructions to render or interpret commands for a graphical user interface (GUI), command-line interface or text user interface; application software such as an office suite, internet access applications, design and manufacturing applications, graphics applications, audio applications, software engineering applications, educational applications, games or miscellaneous applications. Server computer **830** may comprise a web application server that hosts a presentation layer, application layer, and data storage layer, such as a relational database system using a structured query language (SQL) or no SQL, an object store, a graph database, a flat file system or other data storage.

Computer system **800** can send messages and receive data and instructions, including program code, through the network(s), network link **820**, and communication interface **818**. In the Internet example, server computer **830** might transmit a requested code for an application program through Internet **828**, ISP **826**, local network **822**, and communication interface **818**. The received code may be executed by processor **804** as it is received and/or stored in storage **810** or other non-volatile storage for later execution.

The execution of instructions, as described in this section, may implement a process in the form of an instance of a computer program that is being executed and consisting of program code and its current activity. Depending on the operating system (OS), a process may be made up of multiple threads of execution that execute instructions concurrently. In this context, a computer program is a passive collection of instructions, while a process may be the actual execution of those instructions. Several processes may be associated with the same program; for example, opening up several instances of the same program often means more than one process is being executed. Multitasking may be implemented to allow multiple processes to share processor **804**. While each processor **804** or core of the processor executes a single task at a time, computer system **800** may be programmed to implement multitasking to allow each processor to switch between tasks that are being executed without having to wait for each task to finish. In an embodiment, switches may be performed when tasks perform input/output operations when a task indicates that it can be switched or on hardware interrupts. Time-sharing may be implemented to allow fast response for interactive user applications by rapidly performing context switches to provide the appearance of concurrent execution of multiple processes. In an embodiment, for security and reliability, an operating system may prevent direct communication between independent processes, providing strictly mediated and controlled inter-process communication functionality.

2.4 Power Distributor

The power distributor **104** is structured to allow the control of the flow of power from the system **100** internally among the various elements and externally to the power grid **105**. For example, the power distributor **104** may include one or more transformers, automatic transfer switches

(ATS), electrical contactors, fuses, relays, electrical panels, and so on. The power distributor **104** may include a first set of terminals structured to electrically and mechanically connect to the power grid **105**, a second set of terminals structured to electrically and mechanically connect to the output terminals of the generator system **103**, and a third set of terminals structured to electrically and mechanically connect to the load **101**.

Moreover, the power distributor **104** is communicably coupled (e.g., either directly or indirectly) to the controller **102** such that the controller **102** can send commands to the power distributor or otherwise control the operations of the components therein. For example, the controller **102** may send commands that cause the power distributor **104** to connect or disconnect to the power grid **105** (e.g., via an ATS). As another example, the controller **102** may monitor the power sent to the power distributor from the generator system **103**.

In some embodiments, the power distributor **104** may include various components that are spread throughout a facility. That is, the components of the power distributor **104** need not be all localized in a single area. Rather, the structure of the power distributor **104** may be in any configuration that allows for the selective interconnection of electrical power between the load **101**, the generator system **103**, and/or the power grid **105** in accordance with the operations described herein.

3. Functional Overview

The preceding section has described the complete structure of an example power generation system **103** and a load **101** comprising multiple sub-loads **110a-c**. The same structural elements as described in the preceding section also can be utilized in a method of operating the power generation system **103** to optimize the system and reduce the amount of waste. As indicated above, the operations described with reference to each method may be implemented via the execution of the non-transitory computer-readable instructions by the one or more processors of the controller **102**. The operations described for each method are meant to be exemplary and are not limited to a particular order nor confined to a particular implementation. For example, a combination of the operations described with reference to a first method may be performed concurrently or interconnectively with operations described with reference to a second method.

FIG. 4 illustrates a first method **400** of operating the principal functional elements of the system by which one embodiment of the disclosed technology could be implemented. For example, first method **400** includes monitoring the status of the electrical capacity of the generator system to dynamically control the load **101** to optimize the power usage of the generator system and reduce potentially harmful waste.

In an operation **401**, the controller **102** determines the number of sub-loads that are available. In some embodiments, the controller **102** is manually programmed with data (e.g., within a variable) that indicates the number of sub-loads that are part of the load **101**. For example, the controller **102** may be programmed with information (e.g., within objects or within a look-up table) that the load **101** is a particular electrical load size (e.g., 500 kW) and that there are ten (10) sub-loads of the load **101** that are each connected to the power source via a respective electrical contactor **201a-n**. In some embodiments, the sub-loads are of equal size (e.g., 50 kW). In some embodiments, the sub-

loads may each have different sizes (e.g., 10 kW, 50 kW, etc.). In an embodiment, the controller **102** can reference which electrical contactor **201a-n** is connected to each particular sub-load. For example, the controller **102** may have a look-up table or map stored that correlates each sub-load to a particular electrical contactor (or set of contactors) **201a-n** and/or correlates the communication addresses of each device within the sub-loads to the particular electrical contactor **201a-n**. In some embodiments, the electrical load size of each of the sub-loads may be stored in a reference table.

Alternatively or additionally, the controller **102** may be able to dynamically determine the electrical load size of each of the sub-loads and/or update the reference table based upon the dynamic determination. As one example, the controller **102** may receive signals from respective monitoring devices/sensors structured to measure the voltage, amperage, and/or power flow of the respective sub-load to determine an average power and/or peak power consumed by the particular sub-load when connected to power. That is, the controller **102** may be configured to store the historical data of the power usage corresponding to each of the sub-loads and reference that data to calculate or estimate the electrical power load of the respective sub-load.

As another example, the controller **102** may be communicably coupled to one or more contactors, contacts, fuses, or breakers connected in parallel within the sub-load and determine the anticipated electrical power load based on the number. For example, a sub-load may have ten (10) or more breakers **220a-f** connected in parallel within a sub-load **202a-n** that can each handle a particular amperage. The breakers may be communicably coupled to the controller **102** such that the controller is able to monitor the status of the breaker and/or control the status of the respective breaker **220a-f**. The controller **102** may then be able to calculate or estimate, based on the number of breakers in parallel, the status of the breakers, and the size of each of the breakers, the total electrical power load of the sub-load.

As another example, the controller **102** may receive a fault signal from one or more of the electrical contactors **201a-b** that indicates the to the controller **102** that the sub-load corresponding to the faulted electrical contactor is not available to be connected to the power source. In response, the controller **102** may flag that particular sub-load, disconnect all electrical contactors to that sub-load, and/or generate a message to an administrator or operator of the system. In various embodiments, the message may include an alarm located on the controller, an alarm on a display (e.g., HMI) of the controller **102**, an automatically generated e-mail or text message, and so on.

In an operation **402**, the controller **102** receives data representing the power generation output of the generator set. In an embodiment, the data may be received in real time or near real time and the data may represent a then-current power generation output of the generator set. In some embodiments, the controller **102** receives information regarding a status of the generator system **103** that represents the power generation output of the generator set. For example, the controller **102** may receive electrical signals from one or more devices and sensors of the generator system **103** that indicate the number of generators running, faulted, or off, the engine speed of each engine, the oxygen and methane content of the gas being input into the generator engines, and the output of electricity from the generator. The controller **102** may monitor this data over time and store this data to create predictive models of the electrical output of the generator system **103** based on the sensed conditions.

The power generation output (e.g., anticipated power output and/or power output limits) may be estimated via a machine learning model using the received data as inputs, calculated using one or more equations using the received data as inputs, or determined based on other operations such as a look-up table of historical information of the received data and respective electrical output or a pre-programmed look-up table of the received data and respective electrical output.

In some embodiments, the controller **102** may monitor data from devices/sensors on the intake system **303** of the generator system such as the landfill gas blower skid including blower motor speed, methane content, gas flow, after-cooler temperatures, and other vital data points to optimize the flow of landfill gas into the blower skid and out into the biogas generator. The controller **102** may execute one or more operations that cause the operation of the devices of the intake system (e.g., blower speed, temperature setting, compressor speed, and so on) to optimize the power output of the generator system **103**. For example, the controller **102** may monitor the data from the devices/sensors on the intake system **303** and cause the compressor to speed up if the methane content of the gas falls below a threshold (e.g., falls below 40%). The controller **102** may send these commands back to the intake system **303** to implement the command and the controller **102** can then estimate or anticipate the power generation of the generator system **103** based on the new settings of the generator system **103** (e.g., new settings of the compressor) and the sensed conditions of the gas used by the engines in the generator system **103**. In this way, the controller **102** can optimize the composition of fuel into the engine via controlling the blower skid devices and thereby the output of electricity from the generator end of the engine.

In some embodiments, the controller **102** may monitor data from devices/sensors of the generator engines of the generator set such as the engine speed, engine on/off, engine trip, oxygen, methane content, gas flows and other vital data points to optimize the input of fuel into the engine and the output of electricity from the generator end of the engine **311**. For example, the data received from the devices and/or sensors installed on the generator engines allow for the controller to determine the current status of the engines including the composition and flow of fuel into the engines. This allows the controller **102** to estimate the almost immediate output horsepower of the engine and thereby the resulting electrical power output of the generator system.

In an operation **403**, the controller **102** determines which of the available sub-loads to connect. For example, the controller **102** may match the electrical output and the anticipated electrical output to an equal (or lesser) load by determining which of the available sub-loads to connect. In some embodiments, the controller **102** may take the electrical output and the anticipated electrical output of the generator system **103**, apply a margin of safety such as 80%, 90%, 95%, or like the anticipated electrical output of the generator system **103** and then determine which of the sub-loads should be connected to optimally balance the load and the generator system **103**.

In some embodiments, the sub-loads may have a priority associated with each of the sub-loads. For example, if there are ten (10) sub-loads, the first sub-load may have the highest priority of three (3) and the other sub-loads may have a lower priority of two (2). In this example, the sub-load with the highest priority (e.g., the first sub-load) will be determined to be connected first and the other sub-loads may be added in a particular order (e.g., sequentially) until the load is balanced with the output of the generator **301**. In another example, the controller **102** may

determine that a particular heavy sub-load (e.g., 50 kW) cannot be added without overloading the system and instead add a smaller sub-load (e.g., 10 kW) to balance the load as closely as possible.

In an operation **404**, the controller **102** controls the respective electrical contactors of the determined sub-loads to provide electricity to the determined sub-loads. For example, the controller **102** may transmit an electrical signal that causes the respective electrical contactors **201a-d** to turn on (e.g., electrically conduct) to connect the determined sub-loads to the electrical power supplied by the generator system **103**. In some embodiments, the controller **102** may utilize a look-up table to determine which electrical contactor (e.g., via a corresponding address of an output control terminal) is to receive the command to turn on. In this way, the controller **102** can dynamically control the total size of the load **101** to optimize the power usage of the power generated by the generator system **103**.

It is to be appreciated that method **400** or operations thereof may be performed recursively at set time intervals, according to a pre-set schedule, or in response to one of the monitored sensors outputting a reading that breaches (e.g., exceeds or falls below) a threshold value. That is, the controller **102** may continuously monitor the sensors of the generator system and the load **101** in operation **405**. If there is a trigger, then the controller may repeat operations **403** and **404** to ensure the load is balanced and optimized. For example, the controller **102** may be configured to determine the number of sub-loads to connect based on the power generation limits of the generator set at a second time, determine which of the available sub-loads to connect, and control the respective electrical contactors of the determined sub-loads to provide electricity to the determined sub-loads. The second time may correspond to a pre-set interval from a first time where operation **402** was performed or in response to monitored data changing beyond a threshold. For example, if the methane content falls below a particular threshold (e.g., 40%) the controller **102** may be able to anticipate that the electricity output will fall by enough that requires the disconnection of the lowest priority sub-load to prevent overloading the generator and the respective faults that come along therewith. Accordingly, the controller **102** may disconnect the particular sub-load via control of the respective electrical contactors to keep the electrical load level lower than the power generated. As another example, if the controller **102** senses that the actual electrical power output falls below a calculated load level connected to the generator system **103**, then the controller **102** may automatically cause one or more sub-loads to disconnect to prevent over-loading and optimally balance the load to the electrical output of the generator set.

FIG. **5** illustrates a second method **500** of operating the principal functional elements of the system by which one embodiment of the disclosed technology could be implemented. For example, second method **500** includes determining the power generation limits of the generator system, determining an amount of power to be output or received from the power grid, and dynamically controlling the load **101** to optimize the power usage of the generator system and reduce waste.

In operation **501**, the controller determines the power generation limits of the generator system. In some embodiments, operation **501** may be similar or the same as operation **402**. For example, the controller **102** receives various signals from the generator system **103** and can determine a current electrical power output of the generator system and an anticipated electrical power output of the electrical sys-

tem. In some embodiments, the controller **102** may also use data collected via network **106** to determine the power generation limits of the generator or the anticipated electrical power to be output from the generator system **103**. For example, the controller **102** may receive, via an API, weather data. In an embodiment, where the generator system **103** includes wind or solar power sources, the weather data may be used to determine the anticipated electrical power output based on the anticipated wind speed or cloud cover. As one example, the controller **102** may be able to calculate the anticipated electrical power output of the wind turbines based on a pre-set equation that correlates wind speed to anticipated electrical power output. In another example, the controller **102** may reference historical data stored in the memory to correlate wind speeds (e.g., or cloud cover) to the actual power output by the system. Thus, this correlation allows for the controller **102** to estimate the anticipated electrical power based on the sensors of the generator system **103** and third-party data that includes information that will affect the electrical power output of the generator system **103**.

In operation **502**, the controller **102** determines an amount of power to be output or received from the power grid. In some embodiments, the system **100** is to run in an island mode. That is, no electrical power is to be received from the power grid **105** or output to the power grid **105**. Rather, the generator system **103** and the load **101** will use the embodiments described herein to harmoniously optimize the efficiency of the system **100**. However, in some embodiments, a grid operator may request help supporting the grid. The help requested may be in a particular message sent to the controller **102** or in a message sent to an operator that is able to provide commands to the controller to remove the controller **102** from island mode. In particular, the message may be in the form of a request to output a set amount of power to the power grid or to provide a load to the power grid to assist in stabilization of the power grid when there is too much power generation relative to the loads. In an embodiment, the controller **102** may receive signals and/or data that allows the controller to determine a status of the power grid. In an embodiment, the status may allow the controller to determine that the power grid needs a load-sink (i.e., the power grid has more power supply than demand). In response, for example, the controller **102** may respond to this determination by determining a number of sub-loads to connect to system to provide the determined load-sink and transmitting commands that cause the determined number of sub-loads to be connected to the system via the respective electrical contactors.

In some embodiments, the power grid operator may simply request via an API message to the controller **102** (e.g., from a computer of the power grid operator) that the controller **102** monitor the voltage and frequency at the terminals of the power distributor **104** and dynamically provide support to the grid in transient times. That is, the controller **102** may determine that a certain amount of power is needed to be supplied to the power grid **105** or sunk from the power grid **105** based on the monitored voltage and frequency at the terminals.

As another example, the request from the power grid operator may indirectly request support. For example, in some cases, a power grid operator may publish a set price for electricity provided to or pulled from the power grid **105**. The controller **102** may retrieve the price information via an API and calculate based on that price and an estimated cost of kW hours of the generator system **103** whether to pull power from the power grid (e.g., if the price is lower than the

generation cost) or put power on the power grid (e.g., if the grid operator will pay more than the cost of generating by the generator system **103**). As discussed above, the controller **102** can dynamically control the load **101** via controlling the electrical contactors of the sub-loads, thus the system **100** is uniquely able to provide such support to the power grid where other power plants may not be able to in a timely manner.

In operation **503**, the controller **102** dynamically controls the respective electrical contactors of the sub-loads based on the determined power generation limits and the amount of power to be output or received from the power grid. For example, once the controller **102** determines power available based on the power generation limits of the generator system **103** (e.g., the anticipated amount of electrical power) and determines the amount of power to be output to or received from the power grid, then the system can calculate whether there is excess power that needs to be consumed by the load **101** to optimize the system or whether there is not enough excess power. As one example, the controller **102** may determine that the generator system **103** going to output 300 kW of power and the grid operator needs another 200 kW of electrical power sunk from the grid for stabilization purposes in the next hour, then the controller **102** will calculate that there is 500 kW available for the load **101**. The controller **102** may then determine which of the sub-loads to connect to balance the load to 500 kW. In an example where each sub-load is configured to provide an electrical load of 50 kW, then the controller **102** will connect ten (10) of the sub-loads to the power source and control the devices in the power distributor to provide the load to the power grid **105**.

After the system has been balanced for a first time, the controller **102** may continuously monitor the sensors of the generator system and the load **101** in operation **405**. In response to a trigger, such as a time trigger, a new request from the grid operator, or a change in one or more of the monitored sensors, the controller **102** may repeat one or more of operations **501**, **502**, or **503** to cause the system to rebalance. In some embodiments, the rebalancing may include disconnecting one or more of the sub-loads or connecting one or more of the sub-loads via a command sent to one or more respective electrical contactors of the sub-loads. In this way, the system and controller **102** can provide support to the power grid in times when the power grid may need additional support or when the power grid needs an extra load to maintain voltage and frequency levels.

4. Benefits and Improvements

The disclosed embodiments provide numerous benefits and improvements over prior practice. For example, a load having multiple sub-loads that are dynamically connected to power created by a generator system allows for increased efficiency of power usage even when the generator system may be unstable or volatile. This may reduce the need to flare off methane harvested from a landfill, which improves the environmental impact of landfills and biogas generators associated therewith. Moreover, the multiple sub-loads that may be selectively coupled to the power output of the generator system allow for the system to interoperate on a power grid to either provide support to the grid or provide a load to the grid to assist with the stabilization of the voltage and frequency of the power grid.

Moreover, data centers with computers programmed to execute hosting a distributed ledger, mining a cryptocurrency, staking the cryptocurrency, validating the cryptocurrency, or hosting a cloud computing application have con-

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sumed ever-increasing amounts of power as demand for these technologies and their results has increased, but the embodiments of this disclosure can use biogas sources produced from waste decomposition at landfills (or other potentially volatile power sources such as wind and solar) that are located far from inhabited areas and lacking access to power utilities, conventional power grids, substations, or transmission lines. Portioning the data centers allows for the system to optimally balance the number of computers and other equipment online, which optimizes the on-time of the system and ensures that the power generated is efficiently utilized.

Further, embodiments can use landfill gas as a fuel source, even though landfill gas is known to comprise a “dirty” mixture of volatile, naturally corrosive gases, and exits landfills with variable pressure and irregular elemental gas mixtures. As such, these irregular gas mixtures, or weather-dependent power sources, may cause the electrical power generation to be volatile or unstable. The inventors, in an inventive moment, have discovered a combination of physical equipment that solves these challenges and permits an electrically powered portioned out load that may be powered from sources that otherwise would be wasted. The structure of the present disclosure, in a significant advance in the state of the art, enables productive use of biogas from isolated locations without primarily burning biogas as waste via flaring or wasting biogas via venting.

In the foregoing specification, embodiments of the invention have been described with reference to numerous specific details that may vary from implementation to implementation. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense. The sole and exclusive indicator of the scope of the invention, and what is intended by the applicants to be the scope of the invention, is the literal and equivalent scope of the set of claims that issue from this application, in the specific form in which such claims issue, including any subsequent correction.

What is claimed is:

1. A system comprising:

a generator set comprising a first engine, an output terminal coupled to a power distributor, and an intake blower coupled to an intake of the first engine having one or more sensors configured to output data representing at least one of oxygen levels and methane content;

a load comprising two or more sub-loads, wherein each of the sub-loads is coupled to the power distributor via one or more respective electrical contactors; and

a controller that is communicably coupled to the electrical contactors and the generator set, the controller comprising a processor and a memory, the memory storing one or more sequences of computer-readable instructions which, when executed by the processor, cause the processor to execute:

determining a number of sub-loads that are available; receiving data in real time representing a then-current power generation of the generator set;

determining which of the available sub-loads to connect to balance the generator set to the load based on the at least on the data output from the one or more sensors and the then-current power generation of the generator set; and

controlling respective electrical contactors of the determined sub-loads to provide electricity to the determined sub-loads.

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2. The system of claim 1, wherein the load is a data center, and wherein one of the sub-loads comprises a plurality of computing devices, the plurality of computing devices being programmed to execute at least one of: hosting a distributed ledger, mining a cryptocurrency, staking the cryptocurrency, or validating the cryptocurrency, or hosting a cloud computing application.

3. The system of claim 2, the memory further comprising sequences of instructions which, when executed by the processor, cause the processor to execute: receiving data representing an anticipated load of each of the sub-loads and data representing a type of the sub-load, wherein the type of sub-load is used to determine a priority of each sub-load.

4. The system of claim 1, wherein the power distributor is further connected to a power grid.

5. The system of claim 4, wherein the controller is communicably coupled to a network, the memory further comprising sequences of instructions which, when executed by the processor, cause the processor to execute: receiving data representing a status of the power grid via the network; and determining which sub-loads to connect based on the status of the power grid.

6. The system of claim 5, the memory further comprising sequences of instructions which, when executed by the processor, cause the processor to execute controlling the electrical contactors to disconnect all of the sub-loads and output the electricity from the generator set to the power grid when the status of the power grid indicates the power grid needs support.

7. The system of claim 5, the memory further comprising sequences of instructions which, when executed by the processor, cause the processor to execute controlling the electrical contactors to connect sub-loads of more than the determined number of sub-loads when the status of the power grid indicates the power grid needs a load-sink.

8. The system of claim 5, the memory further comprising sequences of instructions which, when executed by the processor, cause the processor to execute receiving the status of the power grid from a computing device of a grid operator, the status comprising a request to output power to the power grid or a request to connect additional loads to the power grid.

9. The system of claim 1, the memory further comprising sequences of instructions which, when executed by the processor, cause the processor to execute:

determining a number of sub-loads to connect based on power generation limits of the generator set at a second time;

determining which of the available sub-loads to connect; and

controlling respective electrical contactors of the determined sub-loads to provide electricity to the determined sub-loads.

10. The system of claim 1, wherein the data representing power generation limits comprises data from the generator set representing engine speed, engine on/off, or engine trip.

11. The system of claim 1, the memory further comprising sequences of instructions which, when executed by the processor, cause the processor to execute calculating based on the data representing power generation limits an anticipated power output of the generator set and determining the number of sub-loads to connect based on the anticipated power output of the generator set.

12. The system of claim 1, further comprising a plurality of sensors on the intake blower of the generator set that are

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configured to output measurements of the data representing the oxygen levels, the methane content, and a gas flow of the intake to the first engine.

13. The system of claim 1, the generator set being configured to operate at 60 Hz and 480V and to provide a power output in a range of 800 to 2500 kVA.

14. The system of claim 1, the generator set comprising two or more engines that are biogas-fueled.

15. A method of operating a grid-connected power system having an integrated data center, the method comprising:

determining, via a controller, a number of sub-loads of a load that are available to be connected to electrical power via respective electrical contactors;

receiving, by the controller, data representing power generation output of a generator set configured to output electrical power that is coupled to the sub-loads via the respective electrical contactors and output data, from one or more sensors, representing at least one of oxygen levels and methane content of biogas being blown into an intake of the generator set;

determining which sub-loads to connect to the electrical power based on the power generation output of the generator set and the output data; and

controlling the respective electrical contactors of the determined sub-loads so as to electrically connect the determined sub-loads.

16. The method of claim 15, further comprising monitoring, by the controller, the output of the one or more sensors of the generator set.

17. The method of claim 16, further comprising determining, by the controller, an anticipated power generation output of the generator set based monitored output of the one or more sensors.

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18. The method of claim 15, further comprising determining, by the controller an amount of power to be output to a power grid coupled to the generator set; and determining which sub-loads to connect to the electrical power based on the power generation output of the generator set and the amount of power to be output to the power grid.

19. A non-transitory computer-readable medium comprising instructions that when executed by one or more processors, are configured to cause the one or more processors to perform:

determining, via a controller, a number of sub-loads of a load that are available to be connected to electrical power via respective electrical contactors;

receiving, by the controller, data representing a status of a generator system configured to output electrical power that is coupled to the sub-loads via the respective electrical contactors;

determining which sub-loads to connect to the electrical power based on the status of the generator system and an anticipated power generation output of the generator system based on a monitored output of one or more sensors of the generator system, wherein the monitored output represents at least one of oxygen levels and methane content of biogas fueling the generator system; and

controlling the respective electrical contactors of the determined sub-loads so as to electrically connect the determined sub-loads.

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