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SYSTEM FOR POWERING AND CONTROLLING AN ELECTRIC MOTOR

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Abstract

A system for powering and controlling an electric motor comprises a generator assembly comprising an engine and an alternator for supplying an alternating current to the electric motor. The alternator comprises a voltage regulator for controlling a voltage of the alternating current, and the engine comprises a throttle controller for controlling a rotational speed of the engine and, therefore, frequency of the alternating current. At least one sensor provides information about an operating environment or condition of the electric motor. A first controller connected to the sensor generates and sends control signals to a second controller based on the information received from the sensor. The second controller is connected to the throttle controller and to the voltage regulator and controls a speed of the electric motor by controlling the throttle controller and the voltage regulator in response to the control signals.

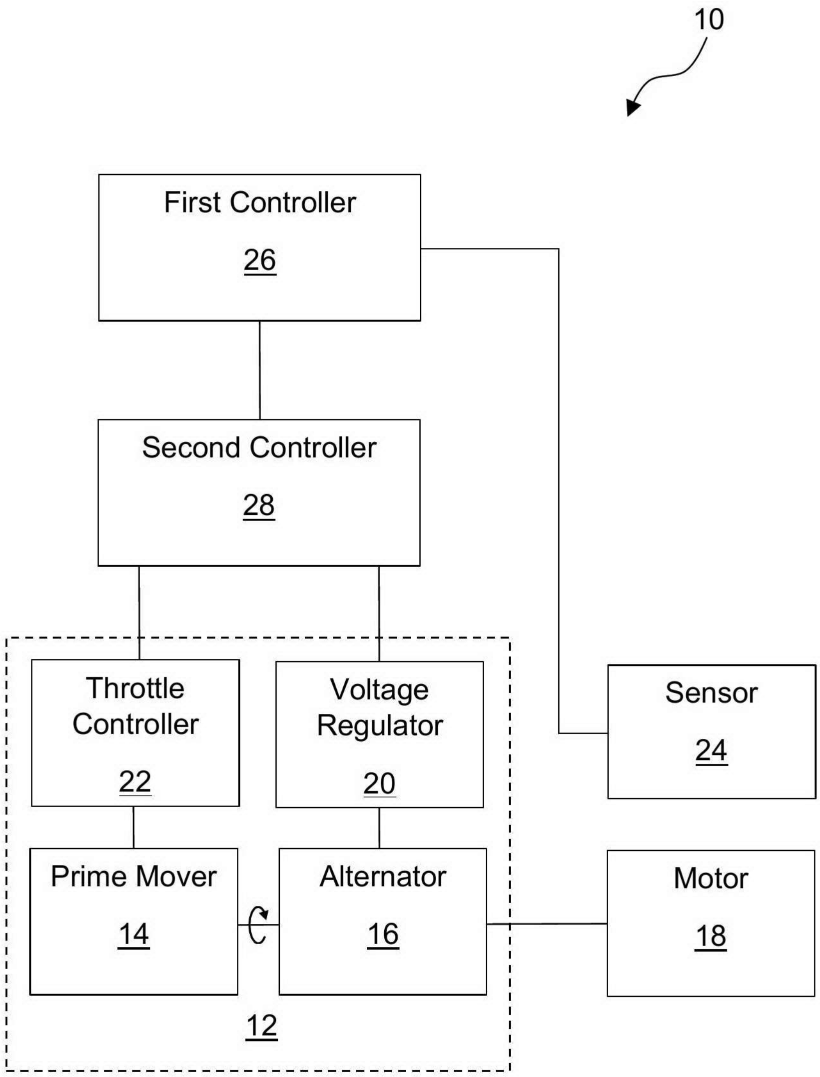
10
First Controller
26
Second Controller
28
Throttle Controller
22
Voltage Regulator
20
Sensor
24
Prime Mover
14
Alternator
16
Motor
18
12

FIG. 1

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SYSTEM FOR POWERING AND CONTROLLING AN ELECTRIC MOTOR

Field

[0001] The present invention relates to electricity generation and, more particularly, to a system for powering and controlling an electric motor.

Background

[0002] A variety of mechanical devices and machines operated by electric motors are often used in remote locations in industry. For example, electric submersible pumps (ESPs) are commonly used to pump oil and water from wellbores and to control groundwater in mining and construction projects. When a grid-based supply of electricity is not available to power a pump, electricity must be created and supplied locally using an electric generator. An electric generator typically comprises a prime mover, such as a reciprocating internal combustion engine or gas turbine, that is mechanically coupled to an alternator to produce AC power.

[0003] The generator may be a fixed-speed generator that is connected to a variable speed drive (VSD) to supply AC power to the pump on a variable-voltage, variable-frequency (VVVF) basis. Alternatively, a variable-speed generator (VSG) may be used, also known as a variable-frequency generator (VFG), that generates and supplies AC power to the pump on a VVVF basis by itself without needing a VSD to modify the output voltage and frequency. A VSG includes a single, integrated system controller that manages and controls the internal generator components that perform the VVVF functionality. The system controller is also commonly connected to one or more sensors that provide information to the controller about various operating and environmental conditions of the pump. The controller implements a closed control loop that automatically adjusts the speed of the pump based on the information received from the sensors. For example, the controller may be configured to maintain a particular set point relating to the pump, such as a desired fluid pressure, level or flow rate.

[0004] Implementing both the VVVF functionality and the control loop functionality in a single controller can present a variety of problems for VSG operators and maintenance

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personnel. For example, if the control loop functionality ceases to function correctly during use, then the VSG must be shut down while the relevant issue is corrected. Further, it is often necessary to update the firmware that implements the control loop, including to fix bugs and install performance optimisations and additional features. The VSG must also be shut down while the firmware is updated. When a VSG is unoperational, this may cause project downtime and significant associated productivity losses.

[0005] It is to be understood that, if any prior art is referred to herein, such reference does not constitute an admission that the prior art forms a part of the common general knowledge in the art, in Australia or any other country.

Summary

[0006] The present invention provides a system for powering and controlling an electric motor, the system comprising:

a generator assembly comprising a prime mover and an alternator for supplying an alternating current to the electric motor, wherein the alternator comprises a voltage regulator for controlling a voltage of the alternating current, and wherein the prime mover comprises a throttle controller for controlling a rotational speed of the prime mover and, therefore, frequency of the alternating current;

at least one sensor to provide information about an operating environment or condition of the electric motor; and

a first controller connected to a second controller, wherein the first controller is connected to the sensor and is configured to generate and send control signals to the second controller based on the information received from the sensor, and wherein the second controller is connected to the throttle controller and to the voltage regulator and is configured to control a speed of the electric motor by controlling the frequency and the voltage of the alternating current by controlling, respectively, the throttle controller and the voltage regulator in response to the control signals.

[0007] The control signals generated by the first controller and sent to the second controller may comprise a target speed of the electric motor, and the second controller may cause the electric motor to operate at the target speed.

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[0008] The first controller may store at least one set point relating to an operating environment or condition of the electric motor. In response to the information received from the sensor, the first controller may determine the target speed such that the set point is maintained.

[0009] The electric motor may operatively drive a pump, such as a submersible or a non submersible pump.

[0010] The set point may relate to an operating environment or condition of the pump.

[0011] The set point may be one of a set of values comprising a desired fluid pressure, a desired fluid flow rate and a desired fluid level.

[0012] The desired fluid pressure may be a fluid outlet pressure of the pump.

[0013] The desired fluid pressure may be a fluid inlet pressure of the pump.

[0014] The desired fluid flow rate may be a fluid outlet flow rate of the pump.

[0015] In examples where the pump is a submersible pump, the desired fluid pressure may be a fluid pressure at a position in a wellbore that the submersible pump is deployed in.

[0016] The set of values may further comprise a maximum temperature of the electric motor.

[0017] The second controller may be configured to send diagnostic information relating to operation of the throttle controller and/or the voltage controller to the first controller. The diagnostic information may be used by the first controller to determine the control signals.

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[0018] The second controller may include protected control logic that can be selectively enabled and disabled. The protected control logic may only be enabled and executed by the second controller once a unique digital key has been input into the second controller using an external device connected to the system.

[0019] When enabled, the protected control logic may cause the second controller to control the speed of the electric motor on a variable basis by controlling the throttle controller and the voltage regulator in response to the control signals.

[0020] When the protected control logic is disabled, the second controller may cause the electric motor to operate at a fixed speed.

[0021] The system may comprise a communications interface for connecting the system to a remote control center or device. The system may be configured to send and receive data to and from the remote control center or device relating to operation of the system via the communications interface.

[0022] The first controller may be configured to operate in accordance with control instructions received from the remote control center or device.

[0023] The first controller may be configured to transmit data relating to operating conditions or parameters of the system to the remote control center or device.

[0024] The first controller may be configured to transmit warnings or alerts to the remote control center or device, wherein the warnings or alerts relate to operating conditions of the system.

[0025] The first controller may be configured to transmit the warnings or alerts when the first controller predicts when the operating conditions of the system may occur or arise.

[0026] The first controller may be configured to predict when the operating conditions of the system may occur or arise based on a mode of operation and/or duration of operation of the system tracked by the first controller.

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[0027] The at least one sensor may be a fluid pressure sensor, fluid flow sensor, fluid level sensor, temperature sensor or vibration sensor.

[0028] The throttle controller may comprise an engine control unit (ECU).

[0029] The throttle controller may comprise an actuated governor.

[0030] The prime mover may comprise a reciprocating internal combustion engine.

[0031] The prime mover may comprise a gas turbine.

[0032] The second controller may be configured to execute a secondary mode of operation, wherein in the secondary mode of operation the second controller controls the throttle controller and the voltage regulator such that the electric motor operates at a fixed speed.

[0033] The second controller may execute the second mode of operation when a signal is sent to the second controller from the remote control center or device.

[0034] The second controller may execute the second mode of operation automatically when the second controller detects that the first controller has either stopped functioning correctly or has been disconnected from the second controller.

[0035] The present invention also provide a method for powering and controlling an electric motor, the method comprising:

using a generator assembly comprising a prime mover and an alternator to supply an alternating current to the electric motor;

controlling a voltage of the alternating current using a voltage regulator of the alternator;

controlling a rotational speed of the prime mover and, therefore, frequency of the alternating current using a throttle controller of the prime mover;

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providing information about an operating environment or condition of the electric motor to a first controller using a sensor;

using the first controller to generate and send control signals to a second controller based on the information received from the sensor; and

using the second controller to control a speed of the electric motor by controlling the frequency and the voltage of the alternating current by controlling, respectively, the throttle controller and the voltage regulator in response to the control signals..

[0036] The method may further comprise:

determining a target speed of the electric motor based on the control signals;

sending the target speed from the first controller to the second controller; and

causing the electric motor to operate at the target speed using the second controller.

[0037] The method may further comprise determining the target speed such that the electric motor maintains at least one set point relating to an operating environment or condition of the electric motor.

[0038] The method may further comprise:

using the electric motor to drive operatively a submersible pump; and

determining the target speed such that the submersible pump maintains a set point relating to an operating environment or condition of the submersible pump.

[0039] The present invention also provides a method for controlling groundwater at a mining or construction site, the method comprising:

using a generator assembly comprising a prime mover and an alternator to supply an alternating current to an electric submersible pump deployed in a wellbore at the site;

controlling a voltage of the alternating current using a voltage regulator of the alternator;

controlling a rotational speed of the prime mover and, therefore, frequency of the alternating current using a throttle controller of the prime mover;

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providing information about a level of water in the wellbore to a first controller using a sensor deployed in the wellbore;

using the first controller to generate and send control signals to a second controller based on the information received from the sensor; and

using the second controller to control a speed of the electric submersible pump by controlling the frequency and the voltage of the alternating current by controlling, respectively, the throttle controller and the voltage regulator in response to the control signals to control the level of water.

Brief Description of Drawings

[0040] Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a system for powering and controlling an electric motor according to an example embodiment of the invention; and

Figure 2 is a schematic diagram of a system for powering and controlling an electric motor according to a further example embodiment of the invention.

Description of Embodiments

[0041] Referring to FIG. 1, an example embodiment of the present invention provides a system 10 for powering and controlling an electric motor. The system 10 comprises a generator assembly 12 that comprises a prime mover 14 and an alternator 16 for supplying an alternating current to an electric motor 18. The alternator 16 comprises a voltage regulator 20 for controlling a voltage of the alternating current. The prime mover 14 comprises a throttle controller 22 for controlling a rotational speed of the prime mover 14 and, therefore, frequency of the alternating current. At least one sensor 24 provides information about an operating environment or condition of the electric motor 18. The system 10 also comprises a first controller 26 that is connected to a second controller 28. The first controller 26 is connected to the sensor 24 and is configured to generate and send control signals to the second controller 28 based on the information received from the sensor 24. The second controller 28 is connected to the throttle controller 22 and to the voltage regulator 20 and is configured to control a speed of the electric motor 18 by controlling the frequency and the voltage of the alternating current by controlling,

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respectively, the throttle controller 22 and the voltage regulator 20 in response to the control signals.

[0042] More particularly, the electric motor 18 may operatively drive any device or mechanism that needs to be operated on a variable speed basis. For example, the electric motor 18 may drive a pump, such as a submersible or non submersible centrifugal or positive displacement pump, a fan or a conveyor system. Referring to the example provided in FIG. 2, the system 10 is shown connected to an electric motor 18 that operatively drives a submersible pump 30. The submersible pump 30 may comprise a centrifugal pump as commonly used in submersible pumps used in the oil and gas industry to pump oil and oil/water mixtures from wellbores (commonly known as “artificial lift” applications) and in mining and construction to extract and control groundwater and/or surface water bodies at worksites (commonly known as “dewatering” applications). The electric motor 18 may be powered by an alternating current (AC) and may comprise an AC induction or synchronous motor.

[0043] As depicted in FIG. 2, the prime mover 14 included in the system 10 may comprise a reciprocating internal combustion engine 14, such as a diesel or petrol engine, that operatively drives the alternator 16 to produce AC electrical power. In other examples, the prime mover 14 may comprise a gas, steam, water or wind turbine. The throttle controller 22 may comprise an actuated governor or, as depicted in FIG. 2, an engine control unit (ECU) 22 that controls electrically the fuel supplied to the engine 14 to control the speed of the engine 14. The second controller 28 may send control signals to the ECU 22 to vary the speed of the engine and, consequently, the frequency of the alternating current generated by the alternator 16.

[0044] The alternator 16 may comprise an excitation system provided with field coils. In such examples, an excitation current (typically a direct current) flowing through the field coils determines the voltage of the alternating current that is generated by the alternator 16. In other examples, the alternator 16 may be a permanent magnet synchronous alternator, wherein excitation power of the excitation system is derived from permanent magnets provided on the rotor of the alternator 16. The voltage regulator 20 may be an automatic voltage regulator (AVR) 20 that receives a target output voltage from the second controller 28 and operatively controls the excitation system on an automatic

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basis such that the alternating current output from the alternator 18 matches the required target voltage.

[0045] The AVR 20 may either intermittently receive a sequence of target output voltages from the second controller 28 over time, or the AVR 20 may receive a continuous signal from the second controller 28 representing the target voltage to be achieved. The AVR 20 and alternator 16 may be configured such that an output voltage falling within a wide range may be produced by the generator assembly 12. For example, the generator assembly 12 may be configured to produce an output voltage of between 400V and 4,800V to allow the system 10 to power and control submersible pumps 30 used in a wide range of applications. This includes, for example: (i) for groundwater control applications in mining and construction, where output voltages of between 400V – 1100V are often required to power submersible pumps deployed in wellbores up to 500m deep; and (ii) for artificial lift applications in the petroleum industry, where higher output voltages up to 4,800V may be required to power submersible pumps deployed in wellbores up to or in excess of 3,000m deep. The system 10 may be provided with a step-up or a step-down transformer (not shown) connected between the generator assembly 12 and the motor 18 if the range of voltages that can be supplied to the motor 18 needs to be changed.

[0046] The second controller 28 may comprise discrete control logic that, when executing, causes the second controller 28 to vary the motor’s 18 speed in accordance with the control signals issued by the first controller 26 by, as described above — i.e., by using the ECU 22 and AVR 20 to control the frequency and voltage of the alternating current supplied to the motor 12. This control logic may be protected such that the control logic can be selectively enabled and disabled. For example, the second controller 28 may be configured such that the control logic is enabled and executed by the second controller 28 only once a unique digital key 32 has been input into the second controller 28. When the control logic is enabled, the second controller 28 provides for variable speed control of the motor 18 in the manner described above. When the control logic is disabled, the second controller 28 may execute a secondary mode of operation wherein the electric motor 18 is caused to operate at a fixed speed only.

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[0047] The key 32 may be entered into the second controller 28 using an electronic user interface (UI) device that is connectable to the second controller 28 using a wired or wireless connection means. In one example, the key 32 may be entered into the second controller 28 via the first controller 26 using a user interface (UI) device 34 connected to the first controller 26. The UI device 34 may be integrated within a control panel that is attached to an external surface of a housing of the system 10. The UI device may comprise an interactive touchscreen display, or a set of pressable buttons or a keypad, that allows the key 32 to be entered. The second controller 28 may be deployed inside the housing of the system 10 such that it is not accessible by operators and maintenance personnel.

[0048] In further examples, the second controller 28 may include functionality that allows the protected control logic to be disabled even when the correct key 32 has been entered into the second controller 28. In one example, the second controller 28 may disable the control logic and enter into the secondary mode of operation when it receives an explicit instruction to do so from a remote control center or device connected to the system 10. In another example, the second controller 28 may disable the control logic automatically when the second controller 28 detects that the first controller 26 has either stopped functioning correctly during use or has been disconnected from the second controller 28.

[0049] The motor control signals that are issued by the first controller 26 to the second controller 28 may comprise a target speed of the pump's motor 18 that is to be achieved by the second controller 28 using the control logic described above. The system 10 may be configured such that the second controller 28 either receives a sequence of target speeds at intervals from the first controller 26 over time, or receives a continuous signal representing the target motor speed.

[0050] The first controller 26 may also comprise a storage device which stores at least one set point relating to the operating environment or condition of the electric motor 18 or pump 30. The first controller 26 may be configured such that in response to the information received from the sensor 24, the first controller 26 determines the target speed that is sent to the second controller 28 that causes the set point to be maintained. For example, in applications where the motor 18 drives a submersible pump 30, the set

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point may relate to an operating environment of the pump 30 such as either (i) a desired fluid pressure, (ii) a desired fluid flow rate and/or (iii) a desired fluid level that is to be maintained by the pump 30. The fluid pressure may be a pressure at an inlet or at an outlet of the pump 30 or at a particular position within a column of fluid in a wellbore that the pump 30 is deployed in. The fluid flow rate may be a flow rate in a fluid outlet of the pump 30 or in a tube connected to such fluid outlet. Instead of a fixed value to be maintained by the pump 30, the set point may be a maximum or minimum value that a particular pump operating or environmental parameter must not exceed or fall below respectively, such as maximum fluid pressure, flow rate or level. In other examples, the set point may relate to an operating condition of the motor 18, such as a fixed or maximum operating temperature of the motor 18 or a maximum mechanical vibration level. The first controller 26 may store and maintain any one of the foregoing set points. In other examples, the first controller 26 may store a set consisting of two or more of the foregoing set points (in any combination) and operate to maintain one of the set points included in the set selectively at any one point in time. The relevant set point in the set that is actively maintained by the system 10 may be selected by an operator of the system 10 using the UI device 34. The UI device 34 may also be used to modify the value(s) of the relevant set point(s). In other examples, the first controller 26 may comprise logic that determines the relevant set point that needs to be maintained automatically based on information received from the sensor 24, or from a set of sensors connected to the first controller 26.

[0051] The sensor 24 may comprise a fluid pressure sensor, fluid flow rate sensor, fluid level sensor, temperature sensor, mechanical vibration sensor or any other type of sensor that provides information allowing the relevant set point to be maintained. In examples where a fluid level set point needs to be maintained, such as a level of water in a borehole for dewatering applications, the sensor 24 may be a hydrostatic sensor that operates by measuring a fluid pressure indicative of the relevant fluid level. The sensor 24 may also be a guided radar device, an ultrasonic device, a magnetostrictive level transmitter or a conductivity sensor when required to measure a fluid level. In such examples, if the fluid level in the borehole rises above the set level in use, the first controller 26 may automatically increase the speed of the motor 18 such that the submersible pump 30 works harder to bring the fluid level down to the set level (and vice

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versa if the fluid level falls below the set level). In other examples, the motor 18 may be controlled by the first controller 26 such that a particular pump operating or environmental parameter is kept between a range of values stored in the first controller 26, such as between a maximum and a minimum wellbore water or fluid level.

[0052] The first and second controllers 26, 28 may each comprise a processor, a programmable logic controller (PLC), a programmable logic array (PLA) or similar electronic controller device. Each controller 26, 28 may comprise a single integrated electronic controller device or multiple controller devices (including multiple processors or PLAs) connected together via a network, bus or similar communications system. In examples where one (or both) of the controllers 26, 28 comprises a processor, each processor will typically comprise a device that is capable of executing instructions encoding arithmetic, logical and/or I/O operations. The processor may, for example, comprise an arithmetic logic unit (ALU), a control unit and a plurality of registers. The processor may comprise a single core processor capable of executing one instruction at a time (or process a single pipeline of instructions) or a multi-core processor which simultaneously executes multiple instructions. The processor may be implemented as a single integrated circuit, two or more integrated circuits, or may be a component of a multi-chip module.

[0053] A storage device of the first controller 26 may comprise a volatile or non-volatile memory device, such as RAM, ROM, EEPROM or flash memory, a magnetic or optical disk, a network attached storage (NAS) device or any other device capable of storing data. The storage device may be integral with the first controller 26 or it may be an external storage device in communication with the first controller 26 via a wired or wireless communication means such as, for example, a USB cable, optical fibre, ethernet or WiFi.

[0054] The engine 14 and alternator 16 may each be sized and rated such that the system 10 is capable of supplying the necessary power required by the electric motor 18 based on its speed and torque requirements. For example, where the electric motor 18 is used to drive a submersible pump 30 that is deployed in a wellbore for groundwater control purposes, the system 10 may be configured to supply a total of between 50 and 500 kilowatts (kW) of power to the electric motor 18. In examples where the

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submersible pump 30 deployed in a wellbore for artificial lift purposes in the petroleum industry, the system 10 may be capable of supplying a total of between 50 and 1,500 kW. In other examples, the system 10 may be configured such that it is capable of supplying power within a narrower range, such as between 50-250 kW, 250-500 kW, 500-750 kW, 750-1,000 kW or 1,000 - 1,500 kW.

[0055] In one example, the first controller 26 may be configured to implement a safety feature wherein the speed of the electric motor 18 is reduced when a temperature sensor installed in the motor 18 indicates that the temperature of the motor 18 has met or exceeded a particular maximum value set by an operator of the system 10. The temperature sensor may, for example, comprise a positive temperature coefficient resistor, or similar temperature measuring device, communicatively coupled to the first controller 26. The first controller 26 may also be configured to stop the electric motor 18 altogether when the maximum temperature value is exceeded.

[0056] The control signals that are issued by the first controller 26 to the second controller 28 may comprise digital control signals. For example, the system 10 may comprise a communications bus connecting the two controllers 26, 28 together and the control signals may comprise digital machine code instructions transmitted via the communications bus. In other examples, the two controllers 26, 28 may be connected together via an internal packet-switched network and the control signals may comprise data packets transmitted over the network. The internal network may be a controller area network that implements an industry standard message-based protocol such as CANbus or Modbus. In other examples, the first controller 26 may be configured to issue analogue control signals to the second controller 28. The second controller 28 may also be connected to the throttle controller 22 and to the voltage regulator 20 using any one of the foregoing communication means. The second controller 28 may also be configured to send diagnostic information relating to operation of the throttle controller 22 and/or voltage controller 20 to the first controller 26, and the diagnostic information may be used by the first controller 26 to determine the motor control signals issued to the second controller 28. The second controller 28 may send the diagnostic information to the first controller 26 using any one of the foregoing communication means.

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[0057] The system 10 may also comprise a communications interface 40 for connecting the first controller 26 to a remote control center or device 42. For example, the communications interface 40 may comprise a radio transceiver or network interface that enables the remote control device 42 to be connected via a LAN, WAN, WLAN, the Internet, cellular or mobile network or other computer or digital network. The first controller 26 may be connectable to an individual remote control device 42 that comprises a touch-screen display, or similar electronic user interface, that enables a human operator to set, activate and monitor the operation of the first controller 26 and the system 10 more generally. In other examples, the first controller 26 may be connectable to a remote control centre that contains various UI control devices that human operators may use to control the first controller 26.

[0058] The first controller 26 may also be configured to transmit data relating to operating conditions or parameters of the system 10 to the remote control center or device 42. This enables the operation and performance of the system 10 to be monitored and assessed during use. The first controller 26 may also be configured to operate in accordance with control instructions received from the remote control center or device 42 via the communications interface 40. For example, the user control center or device 42 may be used by an operator to set and store a particular set point on the first controller 26 and cause the first controller 26 to operate in accordance with a control mode corresponding to the set point. For example, if the motor 18 is used to drive a submersible pump 30, the operator may input a constant water flow rate in the first controller 26 and cause the first controller 26 to enter into a pump control mode wherein the speed of the pump 30 is regulated by the system 10 to maintain the constant flow rate during use.

[0059] The first controller 26 may also be configured to transmit warnings or alerts relating to operating conditions of the system 10 to the remote control center or device 42 via the communications interface 40. For example, the first controller 26 may transmit an alert when the temperature of the electric motor 18 exceeds a particular operating range stored on the first controller 26. The first controller 26 may also be configured to transmit warnings or alerts when it predicts when particular operating conditions of the system 10 may occur or arise in the future. The first controller 26 may make such predictions based on the historical mode of operation and/or duration of operation of the system 10 that is tracked and recorded by the first controller 26.

[0060] The first controller 26 and/or second controller 26 may also comprise control logic that automatically switches off non-critical devices and components of the system 10 temporarily to save power when they are not in use. For example, the following devices and components may be temporarily switched off when not in use: (i) one or more powered sensor 24 devices connected to the first controller 26, such as a fluid flow rate meter when the meter is not required, (ii) the touchscreen display of the UI device 34, (iii) lights provided on a trailer or similar supporting structure that the various internal components of the system 10 are attached to.

[0061] A circuit breaker (not shown) may be interconnected between the generator assembly 12 and the electric motor 18 that prevents the electric motor 18 from drawing too much current from the generator assembly 12 during use. The first controller 26 may be communicatively connected to the circuit breaker and be configured to monitor and reset the circuit breaker in accordance with programmed logic executed by the first controller 26 and/or operator instructions manually issued using the remote control centre or device 42.

[0062] As described in the foregoing paragraphs, the motor control methodology that is implemented by the system 10 is split into two functional control processes executed by two separate, cooperating system controllers 26, 28 respectively. That is, the first controller 26 serves as a master controller that implements a control loop to (i) receive information from the sensor 24, (ii) determine whether the motor 18 needs to run faster or slower based on the information and (iii) send a control signal to the second controller 28 representing a desired motor speed. The second controller 28, in turn, serves as a slave controller that controls the ECU 22 and the AVR 20 based on the control signal such that the motor 18 is caused to run at the desired speed. Implementing this cascade control methodology using two separate system controllers 26, 28 provides several practical advantages, including:

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(i) If the first controller 26 ceases to operate correctly during use, then the second controller 28 may continue to operate the electric motor 18 while the first controller 26 is being repaired or replaced. For example, the second controller 28 may continue to operate the motor 18 but on a fixed speed basis, rather than a variable speed basis, during the relevant maintenance period. The first controller 26 may be electrically detachably connected to the second controller 26, for example by a plug and socket arrangement, to allow the first controller 26 to be removed for such maintenance work;

(ii) If firmware embodying the control logic executed by the first controller 26 needs to be updated during use, the firmware can be updated live while the second controller 28 continues to operate the electric motor 18. Again, the second controller 28 may operate the motor 18 on a fixed speed basis during the relevant update period;

(iii) The control logic implemented by the second controller 28 may be protected using a digital key 32 independently of the control logic implemented by the first controller 26. This may allow, for example, a supplier or manufacturer of the system 10 to lock the system 10 in a fixed speed mode and only allow an end user who has the digital key 32 to unlock and use the more-sophisticated variable speed motor functionality.

[0063] Embodiments of the present invention provide systems that are useful for powering and controlling electric motors, including motors of electric submersible pumps, on a variable speed basis in locations and environments where a local power source is required because a grid-based source of electrical power is not available.

[0064] The skilled addressee will appreciate that certain features depicted in the figures may be shown for simplicity and clarity and have not necessarily been shown to scale. For example, the dimensions and/or relative positioning of some of the features may be exaggerated relative to other features to facilitate an understanding of the various example embodiments exemplifying the principles described herein. Also, common but well understood features that are useful or necessary in a commercially feasible embodiment may not be depicted in order to provide a less obstructed view of these various examples. It will also be understood that the terms and expressions used herein

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adopt the ordinary meaning as is accorded to such terms and expressions with respect to their corresponding respective areas of inquiry and study except where specific meanings have otherwise been set forth herein. The location and disposition of the features depicted in the figures may vary according to the particular arrangements of the embodiment(s) as well as of the particular applications of such embodiment(s).

[0065] Any method steps, processes and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0066] For the purpose of this specification, the word “comprising” means “including but not limited to”, and the word "comprises" has a corresponding meaning.

[0067] The above embodiments have been described by way of example only and modifications are possible within the scope of the claims that follow.

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Claims

1. A system for powering and controlling an electric motor, the system comprising:

a generator assembly comprising an engine and an alternator for supplying an alternating current to the electric motor, wherein the alternator comprises a voltage regulator for controlling a voltage of the alternating current, and wherein the engine comprises a throttle controller for controlling a rotational speed of the engine and, therefore, frequency of the alternating current;

at least one sensor to provide information about an operating environment or condition of the electric motor; and

a first controller connected to a second controller, wherein the first controller is connected to the sensor and is configured to generate and send control signals to the second controller based on the information received from the sensor, and wherein the second controller is connected to the throttle controller and to the voltage regulator and is configured to control a speed of the electric motor by controlling the frequency and the voltage of the alternating current by controlling, respectively, the throttle controller and the voltage regulator in response to the control signals.

2. The system according to claim 1, wherein the control signals generated by the first controller and sent to the second controller comprise a target speed of the electric motor, and wherein the second controller causes the electric motor to operate at the target speed.

3. The system according to claim 2, wherein the first controller:

stores at least one set point relating to an operating environment or condition of the electric motor; and

in response to the information received from the sensor, determines the target speed such that the set point is maintained.

4. The system according to claim 3, wherein the electric motor operatively drives a submersible pump and the set point relates to an operating environment or condition of the submersible pump.

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5. A method for powering and controlling an electric motor, the method comprising:

using a generator assembly comprising an engine and an alternator to supply an alternating current to the electric motor;

controlling a voltage of the alternating current using a voltage regulator of the alternator;

controlling a rotational speed of the engine and, therefore, frequency of the alternating current using a throttle controller of the engine;

providing information about an operating environment or condition of the electric motor to a first controller using a sensor;

using the first controller to generate and send control signals to a second controller based on the information received by the first controller from the sensor; and

using the second controller to control a speed of the electric motor by controlling the frequency and the voltage of the alternating current by controlling, respectively, the throttle controller and the voltage regulator in response to the control signals.

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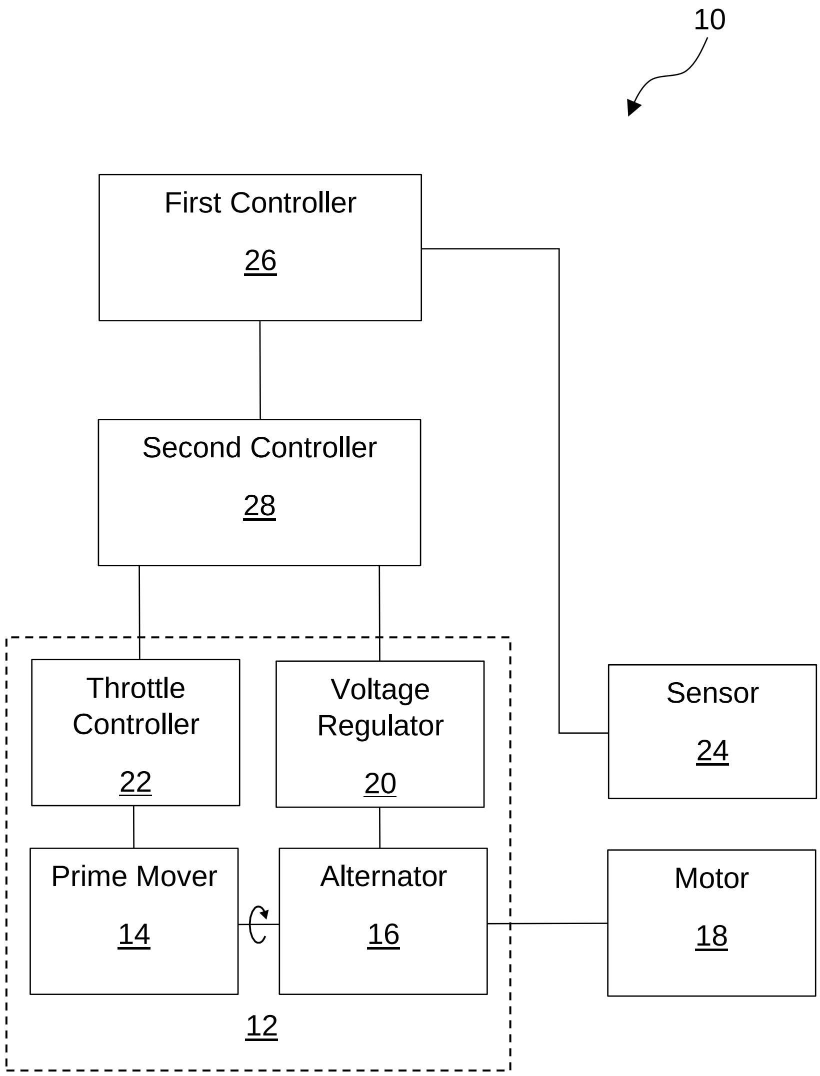

FIG. 1

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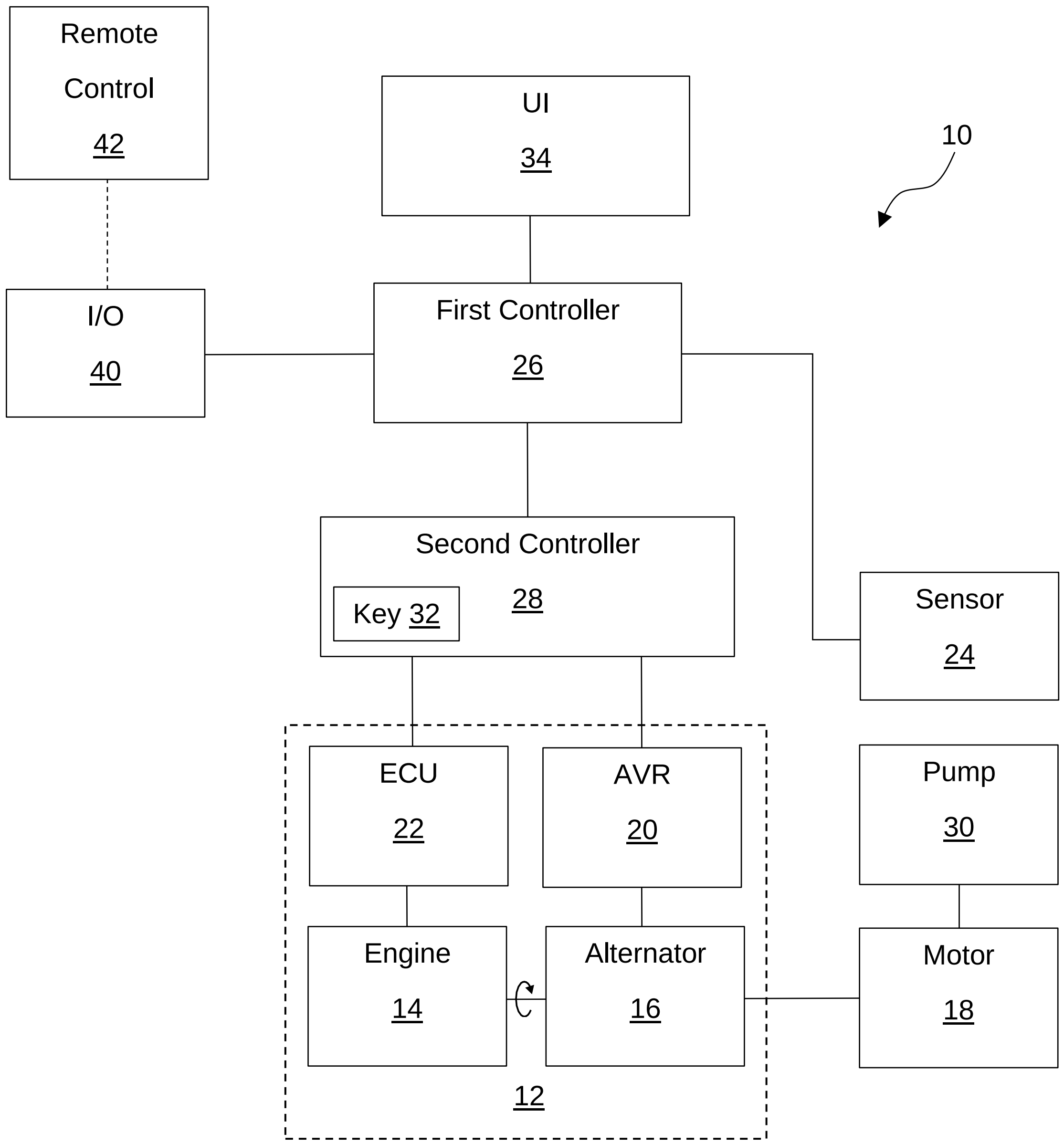

FIG. 2