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BATTERY LOAD TEST IN AGRICULTURAL UTILITY VEHICLE

Abstract

An onboard battery load test system for a utility vehicle. The onboard battery load test system includes a vehicle battery, a primary pump disposed in a fluid circuit and configured to pressurize a fluid in the fluid circuit, a backup pump disposed in the fluid circuit as a redundancy to the primary pump, at least one battery sensor operable to generate a battery sensor signal representative of a condition of the vehicle battery, and a controller operatively coupled with the at least one battery sensor. The controller includes a processor, a memory device operatively coupled with the processor, and battery load test logic stored in the memory device and being executable via the processor to determine health of the vehicle battery by: initiating a current draw on the vehicle battery by the backup pump, receiving the battery sensor signal, and determining the battery health based on the battery sensor signal.

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Background/Summary

FIELD OF DISCLOSURE

[0001] The present disclosure relates to an agricultural vehicle having a battery and to onboard battery testing therefor.

BACKGROUND

[0002] Utility vehicles generally include one or more batteries to power one or more vehicle components or systems. Over time, the ability of a battery to generate required current (even when fully charged) diminishes. Testing the battery can determine when the battery needs to be replaced.

SUMMARY

[0003] The disclosure relates to battery prognostics and onboard testing for battery health.

[0004] Battery load testing may provide a measure of a battery's ability to generate high current. Load testing may include isolating the battery circuit and generating a high load test condition that draws on the battery while the battery circuit is isolated. During the high load draw, data is measured to determine the health of the battery.

[0005] In one aspect, the disclosure provides an onboard battery load test system for a utility vehicle. The onboard battery load test system includes a vehicle battery, a primary pump disposed in a fluid circuit and configured to pressurize a fluid in the fluid circuit, a backup pump disposed in the fluid circuit as a redundancy to the primary pump, at least one battery sensor operable to generate a battery sensor signal representative of a condition of the vehicle battery, and a controller operatively coupled with the at least one battery sensor. The controller includes a processor, a memory device operatively coupled with the processor, and battery load test logic stored in the memory device and being executable via the processor to determine health of the vehicle battery by: initiating a current draw on the vehicle battery by the backup pump, receiving the battery sensor signal, and determining the battery health based on the battery sensor signal.

[0006] In another aspect, the disclosure provides an onboard battery load test system for a utility vehicle. The onboard battery load test system includes a vehicle battery, at least one battery sensor configured to generate signals representative of battery current, battery voltage, and battery temperature, and a controller operatively coupled with the at least one battery sensor. The controller includes a processor, a memory device operatively coupled with the processor, and battery load test logic stored in the memory device and being executable via the processor to determine health of the vehicle battery by: initiating a current draw on the vehicle battery, receiving the battery current, battery voltage, and battery temperature signals during the current draw, and determining the battery health based on the battery current, battery voltage, and battery temperature signals.

[0007] In yet another aspect, the disclosure provides a method for conducting an onboard battery load test to determine health of a vehicle battery in a utility vehicle. The method includes generating, by at least one onboard battery sensor, a battery sensor signal representative of a condition of the vehicle battery. The method also includes executing, via a processor of a controller, battery load test logic stored in a memory device of the controller to determine health of the vehicle battery by: initiating a current draw on the vehicle battery, receiving the battery sensor signal during the current draw, and determining the battery health based on the battery sensor signal.

[0008] Other aspects of the disclosure will become apparent by consideration of the detailed description and accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a side view of a utility vehicle, such as a tractor, having a battery load test system in accordance with one implementation of the present disclosure.

[0010] FIG. **2** is a schematic diagram illustrating a first condition of the battery load test system of the utility vehicle of FIG. **1**.

[0011] FIG. **3** is a schematic diagram illustrating a second condition of the battery load test system of the utility vehicle of FIG. **1**.

[0012] FIG. **4** is a block diagram of a controller associated with the battery load test system of the utility vehicle of FIG. **1**.

[0013] FIG. **5** is a flow chart illustrating battery load test logic associated with the battery load test system of the utility vehicle of FIG. **1**.

DETAILED DESCRIPTION

[0014] Over time, a battery can lose its ability to generate a high current and needs replacing. Battery load testing may provide a measure of a battery's ability to generate high current. For example, load testing the battery over time provides a picture of battery health. Load testing may include isolating the battery circuit and generating a high load test condition that draws on the battery while the battery circuit is isolated. During the high load current draw, data is measured to determine the health of the battery.

[0015] The battery may be part of a utility vehicle having a vehicle alternator connectable to charge the battery. The utility vehicle may have one, two, or more batteries capable of being tested in accordance with the disclosure. Though only one battery need be described herein, it should be understood that the same arrangement and method may be applied to additional batteries in the circuit. Isolating the battery circuit separates the battery from charge current supplied by the vehicle alternator. In some implementations, the alternator may be set to an OFF condition in order to run the battery load test. While the battery is isolated, the battery current may be drawn by a high load component of the vehicle. The battery may continue to power a first set of vehicle components (including controllers as one example) while isolated for the load test. A second set of vehicle components runs directly on the alternator while the battery is isolated. Once the battery is free of charge current, the high load test condition may be generated by turning on the high load component. This simulates an electric starter-like load of the engine at vehicle startup but reduces the impact of variables associated with vehicle startup that can skew battery health test results, such as engine friction and starter health. Using the high load component to conduct a battery load test while the vehicle engine is running (as opposed to using the load of vehicle engine startup) provides a more consistent load on the battery during testing, though the battery load test could also be executed while the engine is not running to achieve a consistent load. Knowledge about the battery health gleaned from the test being performed outside of vehicle engine startup also provides information that is useful for diagnosing issues during the next vehicle engine startup. For example, having battery health data from the last time the vehicle was running can allow diagnostics to count or discount the battery as contributing to any issue detected during the next vehicle engine startup.

[0016] The high load component may be, for example, a pump, a heater, and implement, or other component that draws high current. “High current” may be defined in any suitable way, e.g., in straight amps or as a percentage of the battery cold cranking amps (CCA) rating. (In examples where more than one battery is tested at the same time, the CCA ratings of the batteries should be added together.) In one example, “high current” may mean at least 90 amps, or at least **190** amps in another example. In another example, “high current” may mean at least 10% of the battery CCA rating. In other examples, “high current” may mean at least 12% of the battery CCA rating, at least 15% of the battery CCA rating, etc.

[0017] A high load may additionally or alternatively be defined by momentary current and/or steady state current. Momentary current typically occurs at startup and is generally higher than the steady state current that is reached after startup. The high load may be 90 or more amps momentary current in some examples, 190 or more amps momentary current in other examples, 300 or more amps momentary current in other examples, 400 or more amps momentary current in yet other examples, 500 or more amps momentary current in yet other examples, 600 or more amps momentary current in further examples, 700 or more amps momentary current in yet other examples, etc. The high load may be 50 or more amps steady state current in some examples, 100 or more amps steady state current in other examples, 200 or more amps steady state in other examples, 300 or more amps steady state in yet other examples, 400 or more amps steady state in other examples, 500 or more amps steady state in yet other examples, etc.

[0018] The pump may be, for example, a backup pump. The backup pump may be, for example, a hydraulic pump, a pneumatic pump, etc. In one example, the backup pump may be a backup hydraulic steering and/or braking pump. (It should be understood that steering and braking may utilize the same hydraulic fluid and the terms may therefore be used interchangeably herein. For example, a “steering pump” may additionally or alternatively encompass a “braking pump” and vice versa.) The backup pump is a redundancy should a primary pump fail or need to be brought offline. Using a backup pump advantageously allows the test to occur while the engine of the vehicle is running and without disruption to the operation of the vehicle, though it is possible to run the test using other high load components and obtain useful results.

[0019] The measured data may include battery current, battery voltage, and battery temperature. The battery measurements are indicative of the internal resistance of the battery, which increases with battery age. A high internal resistance of the battery results in a diminished ability of the battery to generate high current and suggests that battery replacement would be advantageous. In some examples, steering fluid pressure may also be measured. The steering fluid pressure measurement indicates whether the steering fluid pump (e.g., the backup steering fluid pump being used for the battery load test) is functioning properly and thus helps determine whether the battery load test results are indicative of battery health or a faulty pump.

[0020] Before any constructions of the disclosure are explained in detail, it is to be understood that the disclosure is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the accompanying drawings. The disclosure is capable of supporting other constructions and of being practiced or of being carried out in various ways.

[0021] FIG. **1** illustrates a utility vehicle **10** having at least one battery **12** and a pressurized fluid circuit **14**, such as a hydraulic circuit. While reference may be made herein to the pressurized fluid circuit **14** being a hydraulic circuit, it should be understood that the pressurized circuit **14** may alternatively be a pneumatic circuit, or any other pressurized fluid circuit. The utility vehicle **10** may be embodied as an agricultural vehicle, a construction vehicle, a forestry vehicle, a mining vehicle, or any other utility vehicle having a pressurized fluid circuit **14**. In the illustrated example of FIG. **1**, the utility vehicle **10** may be an agricultural tractor.

[0022] The battery **12** may have any suitable rechargeable chemistry, such as a lithium-ion chemistry or a nickel-cobalt-aluminum (NCA) chemistry. The term “battery,” as appearing herein, is utilized in a broad sense to refer to any rechargeable battery, rechargeable battery pack, rechargeable battery apparatus or device, rechargeable energy storage device, regardless of the number and type of individual cells contained therein.

[0023] The pressurized fluid circuit **14** may include a primary pump **16** and a backup pump **18**. The primary pump **16** mainly pressurizes fluid in the circuit **14**, and the backup pump **18** is a redundancy in case of failure of the primary pump **16** or in case the engine stops running while the vehicle is still moving. Under normal operating conditions, the primary pump **16** pressurizes fluid in the pressurized fluid circuit **14** and the backup pump **18** is in an OFF condition. The backup pump **18** may be electrically driven and operable to pressurize fluid in the pressurized fluid circuit **14** when the primary pump **16** is inactive (e.g., is suffering performance issues, is isolated from the circuit **14**, is in an OFF condition, or when the engine is not running, etc.). The backup pump **18** may be fluidly arranged in parallel with the primary pump **16** in the circuit **14**.

[0024] In some implementations, the primary pump **16** is engine driven (e.g., driven by a prime mover **24**). In other implementations, the primary pump **16** may be driven electrically.

[0025] The utility vehicle **10** may include a plurality of wheels **20**, such as wheels with tires or tracks for engaging the ground G, and a chassis **22** supported by the wheels **20**. In some implementations, the utility vehicle may include the prime mover **24** for powering tractive effort. The prime mover **24** may include an internal combustion engine, an electric vehicle battery, or any other suitable source of power for tractive effort. The prime mover **24** may be operatively coupled to a starter motor **26** for starting the prime mover **24**. In the illustrated example, the utility vehicle **10** may also include a cabin **28** supported by the chassis **22**.

[0026] The utility vehicle **10** may include an alternator **30** electrically connectable to charge the battery **12**. The battery **12** may be operable to provide power to the starter motor **26** and the backup pump **18**, as well as a first set of vehicle components **32** and a second set of vehicle components **34** (FIGS. **2-3**). In some implementations, where the primary pump **16** is electrically driven, the battery **12** may also be operable to provide power to the primary pump **16**.

[0027] The first set of vehicle components **32** may include controllers and interfaces, which may be located in the cabin **28** or in any other suitable location. In one example, the first set of vehicle components **32** includes the controller **200** described in greater detail below. The first set of vehicle components **32** may additionally or alternatively include other components or controllers (which may be integrated with or separate from the controller **200**) such as a steering and braking controller, a CAB controller including transmission interface logic, an automatic temperature controller, a radio, an armrest controller, etc. The second set of vehicle components **34** may include the primary pump **16** and/or other components. The second set of vehicle components **34** may include other components or controllers (which may be integrated with or separate from the controller **200**), such as an engine controller (ECU), a steering and braking controller, a vehicle controller, etc. In other examples, the first set of vehicle components **32** and the second set of vehicle components **34** may each include any suitable combination of components.

[0028] With reference to FIGS. **1** and **4**, the utility vehicle **10** also includes a human-machine interface (HMI) **42** (e.g., including a display and input members, such as any combination of one or more of buttons, dials, joysticks, mouse pads, a touch screen, a graphical user interface, or the like) with which the operator can input settings, preferences, commands, etc. to control the utility vehicle **10**. The operator may also input settings, preferences, commands, etc. remotely. For example, the utility vehicle **10** may be in remote two-way communication with an operations center **44** located remotely from the utility vehicle **10**, e.g., by wireless electronic signals such as but not limited to satellite, internet, mobile telecommunications technology, Bluetooth, radio, a frequency, a wavelength, etc. A remote operator at the operations center **44** may send and receive signals to and from the utility vehicle **10**. The operations center **44** may include a controller having a memory device and a processor configured as described with respect to the controller **200** disclosed herein. Thus, the operations center **44** may receive and store data sent by the utility vehicle **10**, as well as other utility vehicles. A group of utility vehicles may be referred to herein as a fleet of utility vehicles, regardless of ownership. For example, each vehicle in the fleet may have a common characteristic, such as being from the same manufacturer or being equipped to broadcast the same type of data to the operations center **44** so the operations center **44** can analyze trends across the population of vehicles (at a population level).

[0029] A battery load test system **100** may be employed to test the ability of the battery **12** to generate a high current (also referred to herein as “battery health”). The battery load test system **100** may include a battery current sensor **230**, a battery voltage sensor **232**, and a battery temperature sensor **234**. The battery sensors **230**, **232**, **234** may be coupled to the battery **12** to measure battery current, battery voltage, and battery temperature, respectively. The battery sensors

230, **232**, **234** may be configured to sense these conditions from the battery negative terminal. In the illustrated example, the battery sensors **230**, **232**, **234** may be configured as a single sensor unit **228**. However, in other implementations, separate battery sensors **230**, **232**, **234** could be used for some or all of the measurements. The vehicle **10** may include more than one battery and more than one sensor(s). For example, the vehicle **10** may include a second battery **12′** and corresponding battery sensors **230′**, **232′**, **234′** which may be configured as a single sensor unit **228′**. Thus, the battery load test system **100** may be used to test more than one battery **12**.

[0030] The battery load test system **100** also includes an alternator/battery relay **38** and a backup pump relay **40**. The alternator/battery relay **38**, when closed, provides electrical communication between the alternator **30** and the battery **12** such that the battery **12** is chargeable by the alternator **30**. When open (FIGS. **2-3**), the alternator/battery relay **38** electrically isolates the battery **12** from the alternator **30** such that the battery **12** is not charged. Also, when the alternator/battery relay **38** is open, the alternator **30** is operable to provide power to the second set of vehicle components **34** (bypassing the battery **12**) while the battery **12** is operable to provide power to the first set of vehicle components **32**. The backup pump relay **40**, when open (FIG. **2**), disconnects power to the backup pump **18** such that the backup pump **18** is OFF. When closed (FIG. **3**), the backup pump relay **40** allows current to flow from the battery **12** to the backup pump **18**.

[0031] Additionally or alternatively, the battery load test system **100** may include a primary pump relay **41** (for implementations where the primary pump **16** is driven electrically) configured to be operable and controllable in the same way as the backup pump relay **40** described herein. The primary pump relay **41** may be used to electrically connect the battery **12** to the primary pump **16** during a battery load test.

[0032] Operation of the primary pump **16** and the backup pump **18** may be controllable via a controller **200**. The controller **200** may include a bus **210** or other communication mechanism for communicating information and a processor **202** coupled with the bus **210** for processing information. The controller **200** includes a main memory **204**, which may comprise random access memory (RAM) **212** or other dynamic storage devices for storing information and instructions such as battery load test logic **206** to be executed by the processor **202**, and read only memory (ROM) **216** or other static storage device for storing static information and instructions for the processor **202**. The main memory **204** may be a non-transitory, non-volatile memory device and operable to store information and instructions executable by the processor **202**. The controller **200** can be programmed in a way that sets the duration of testing intervals and/or allows an operator to initiate a battery load test when such battery information is desired (e.g., when there are concerns about battery health). The term “controller” as used herein may encompass a single controller or a group of controllers in communication with each other, in which case each controller in the group of controllers need perform only a portion of the functionality of the controller **200**. The term “operator” as used herein is meant to encompass a vehicle operator (such as a driver, farmer, vehicle owner, etc.), a dealer of utility vehicles, a service technician, and/or another individual or entity associated with the storage, use, sale, maintenance, or repair of the utility vehicle **10**. A pressure sensor **46** (FIG. **1**) may be configured to measure a fluid pressure associated with fluid pressurized by the backup pump **18** and send corresponding signals (e.g., data signals) to the controller **200**.

[0033] The controller **200** includes an input/output **208** for receiving input signals (e.g., data signals) from the sensors **46**, **230**, **232**, **234** and providing output control signals. The controller **200** may be configured to control the alternator/battery relay **38** and the backup pump relay **40** for the battery load test. The controller **200** may also be programmed to set battery load test intervals or to set conditions for performing the battery load test, which may be programmed into the battery load test logic **206**. Additionally, the controller **200** and, in particular a communication interface **218** of the controller **200**, may be used to report a failed battery load test (or other battery health information) to a local network **220** and CAN bus **222**. The communication interface **218** may communicate the battery load test results wirelessly to a remote location, such as the operations center **44**. The controller **200** may also send a signal to the HMI **42** to visually display the failed test (or other battery health information). For example, the HMI **42** may display an error code, error symbol, or error description on the display screen.

[0034] The controller **200** may additionally or alternatively be configured to control the primary pump relay **41** in the same way as the backup pump relay **40** described herein to additionally or alternatively run a battery load test using the primary pump **16** as the load. In such implementations, the primary pump **16** is electrically drivable.

[0035] As illustrated in FIGS. **1** and **4**, the HMI **42** is operatively coupled with the controller **200**. The controller **200** is configured to receive signals from the HMI **42** (e.g., control signals) and send signals to the HMI **42** (e.g., display signals). Signals, as used herein, may include wired electronic signals (e.g., by circuit or wire), wireless electronic signals (e.g., by satellite, internet, mobile telecommunications technology, Bluetooth, radio, a frequency, a wavelength), or the like.

[0036] In some implementations, the controller **200** may be located in a separate control box of the vehicle **10**. In other implementations, the battery load test system **100** and corresponding battery load test logic **206** are incorporated with existing controllers of the vehicle **10** such as, for example, the steering and brake control system controller(s). Advantageously, the steering and brake control system controller(s) is already configured to control the alternator/battery relay **38**, control of which is needed to perform the battery load test, though other controllers may be used and configured accordingly. In some implementations, control of the battery load test system **100** may be assigned to one or more of the redundant safety critical controllers on the tractor. In this manner, the battery load test system **100** comprises part of the steering and brake control system controller(s) such as, for example, the A and B box on a tractor. Thus, the battery load test system **100** also includes the battery load test logic **206** associated with the controller **200**.

[0037] FIG. **5** illustrates at least a portion of the battery load test logic **206** in flow chart form. Though steps **302-308** are described in sequential order herein, the steps **302-308** may be performed in other suitable orders, some steps **302-308** may be performed at the same time, and some steps **302-308** may be omitted. It should be understood that any numbering or lettering used herein to list steps, methods, or processes is used for purposes of separating items in a list and does not imply any particular order to the listed steps, methods, or processes.

[0038] At step **301**, the battery load test starts. The battery load test may be performed at any known time. For example, the load test may be performed in response to a predetermined load test trigger condition being met and/or in response to a test initiation signal **214** inputted by an operator, either inputted onboard (e.g., using the HMI **42**) or remotely (e.g., from the operations center **44**). The predetermined load test trigger condition may be programmed into the battery load test logic **206**. For example, the battery load test logic **206** may automatically trigger a test when the vehicle is running and in park and/or other conditions have been met. In another example, the battery load test logic **206** may automatically trigger a test when the vehicle is running and in motion (e.g., first motion of the vehicle) and/or other conditions have been met. The other conditions may include predetermined intervals of time, a vehicle startup condition, and/or at predetermined times of the day such as the end of the day (because it may be useful to know the battery health right before the next day's vehicle engine startup), and/or at any other predetermined state and/or predetermined time. Triggering the test while the vehicle **10** is running is advantageous so the test does not deplete the charge of the battery **12** before the next engine startup, though the test could be performed when the vehicle **10** is not running. The battery load test is an onboard test conducted without an external testing device (e.g., external electrodes, an external load device, etc.) for the primary purpose of testing the battery being brought into contact with the utility vehicle **10**. The component used to load the battery during the battery load test is already onboard the vehicle **10** and/or the sensor(s) used to take measurements during the battery load test are already onboard the vehicle. “Onboard” may include the use of an implement attached to the vehicle **10** as the battery test load component. The implement may be attached to the vehicle **10** for the primary purpose of performing work, such as lifting, loading, pushing, cutting, boring, moving, conveying, collecting, etc., with the use thereof as a battery test load being secondary. The term "onboard" as used herein may encompass systems in which the controller(s) performing some or all of the battery load test is/are disposed onboard and/or remotely from the vehicle **10** by wireless communication.

[0039] Upon initiation of the test, at step **302**, the battery **12** is isolated from the alternator **30**. Isolating the battery circuit separates the battery **12** from charge current supplied by the alternator **30** such that the battery **12** is not charged during the test. To isolate the battery **12**, the battery load test logic **206** is programmed to open the alternator/battery relay **38**, as illustrated in FIG. **2**. In other implementations, the battery load test logic **206** may be programmed to set the alternator **30** to an OFF condition in order to run the battery load test. While the battery **12** is isolated, the first set of vehicle components **32** may draw current **50** from the battery **12**. The first set of vehicle components **32** may include controllers, including the controller **200**. The second set of vehicle components **34** draws current **52** directly on the alternator **30** while the battery **12** is isolated, as illustrated in FIG. **2**.

[0040] Once the battery **12** is free of charge current, at step **303**, the battery load test logic **206** is programmed to initiate a high load vehicle component current draw on the battery **12**. In the illustrated example, the high load vehicle component may be the backup pump **18** onboard the utility vehicle **10**. Using a backup pump advantageously allows the test to occur while the engine of the utility vehicle **10** is running and without disruption to the operation of the utility vehicle **10**, though it is possible to run the test using other high load components and obtain useful results. To initiate a high current draw **54**, the battery load test logic **206** is programmed to close the backup pump relay **40** as illustrated in FIG. **3**, which establishes an electrical connection between the battery **12** and the backup pump **18**. The first set of vehicle components **32** may continue their current draw **50** on the battery **12** during the test, as illustrated. Additionally or alternatively, the battery load test may be run using the primary pump **16** as the high load component (where the primary pump **16** is electrically driven) by closing the primary pump relay **41**. Additionally or alternatively, the battery load test may be run using an implement, a heater, and/or another relatively consistent electrical load as the high load component.

[0041] After the high current draw is initiated, at step **304**, the controller **200** receives and stores sensor data from the battery sensors **230**, **232**, **234** corresponding to battery current, battery voltage, and battery temperature respectively. The battery measurements may be taken during the high current draw **54**. The battery measurements are indicative of the internal resistance of the battery **12**. The battery load test logic **206** may be programmed to store the battery measurements into the main memory **204** and/or into a remote memory device such as one at the operations center **44**, a mobile device, etc.

[0042] At step **305**, the battery load test logic **206** may be programmed to understand battery internal resistance based on the battery measurements. For example, the battery load test logic **206** may be programmed to use the battery measurements to calculate the internal resistance or, alternatively, may rely on a corresponding value (e.g., voltage, a combination of voltage and current, etc.) to inform a battery health determination based on said value(s) related to internal resistance without fully calculating internal resistance. The battery sensors **230**, **232**, **234** are configured to measure voltage in response to a current load at a measured temperature. Each time the battery load test is executed (e.g., each test interval), the internal resistance of the battery **12** may be understood based on the battery sensor measurements. Internal resistance is generally higher when the battery **12** is cold. Having the battery temperature measurement is advantageous to understand whether poor test results are due to the battery **12** degrading or being cold. The battery load test logic **206** may be programmed to store the battery measurements, battery health values, and/or calculations (battery data) into the main memory **204** and/or into a remote memory device such as one at the operations center **44**, a mobile device, etc.

[0043] At step **306**, the battery load test logic **206** may be programmed to make a battery health determination based on the battery data. The battery load test logic **206** may be programmed to make a battery health determination based on the battery data tracked over time. For example, if the internal resistance of the battery **12** appears to be increasing over time and the battery temperature is not decreasing over time, then a negative battery health determination may be made (such as a fail or a low score). (Low battery temperatures can increase internal resistance, so if low temperature can be ruled out as a cause of increasing internal resistance by tracking the data over time, then this helps make a battery health determination.) The battery data from a single utility vehicle **10**, or from more than one utility vehicle **10**, may be analyzed for trends to better understand battery health based on these measurements. The battery health determination may include a battery health score (e.g., on a scale), a pass or fail, a combination of both, etc.
[0044] At step **307**, the battery load test logic **206** may be programmed to generate a test output signal **224** based on the battery health determination to be sent to the operator at step **308** (e.g., to the HMI **42**, by wireless communication, to the operations center **44**, etc.). The test output signal **224** may include information for the operator about the battery health determination, such as the current battery health (e.g., a health score), the battery health over time, a battery pass indication, a battery failure warning, a battery replacement recommendation, etc. The test output signal **224** may provide the information in words, symbols, indicia, pictures, sounds, a light, etc., or any combination thereof. The test output signal **224** may additionally or alternatively activate an alert device such as, for example, an audible alarm and/or flashing light to notify the operator of the test results. The test output signal **224** need not be generated and/or sent every time the load test is executed. In some implementations, the test output signal **224** is only generated and sent when there is a concern about the battery health (e.g., negative test results) and/or when an operator initiates the battery load test. In other implementations, the test output signal **224** is generated and sent each time the battery load test is executed. After the test output signal **224** is sent, the battery load test ends at **309**. However, the battery load test may end after step **306** if there is no need to generate and send the test output signal **224**.
[0045] The terminology used herein is for the purpose of describing example embodiments or implementations and is not intended to be limiting of the disclosure. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the any use of the terms "has," "includes," "comprises," or the like, in this specification, identifies the presence of stated features, integers, steps, operations, elements, and/or components, but does not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.
[0046] The teachings may be described herein in terms of functional and/or logical block components or various processing steps, which may be comprised of any number of hardware, software, and/or firmware components configured to perform the specified functions.
[0047] Terms of degree, such as "generally," "substantially," or "approximately" are understood by those having ordinary skill in the art to refer to reasonable ranges outside of a given value or orientation, for example, general tolerances or positional relationships associated with manufacturing, assembly, and use of the described embodiments or implementations.
[0048] As used herein, "e.g.," is utilized to non-exhaustively list examples and carries the same meaning as alternative illustrative phrases such as "including," "including, but not limited to," and "including without limitation." Unless otherwise limited or modified, lists with elements that are separated by conjunctive terms (e.g., "and") and that are also preceded by the phrase "one or more of" or "at least one of" indicate configurations or arrangements that potentially include individual elements of the list, or any combination thereof. For example, "at least one of A, B, and C" or "one or more of A, B, and C" indicates the possibilities of only A, only B, only C, or any combination of two or more of A, B, and C (e.g., A and B; B and C; A and C; or A, B, and C).

[0049] Thus, the disclosure provides, among other things, a battery load test system for conducting an onboard battery load test using a high load component of the utility vehicle while the utility vehicle is running. Various features and advantages of the disclosure are set forth in the following claims.

Claims

1. An onboard battery load test system for a utility vehicle, the onboard battery load test system comprising: a vehicle battery; a primary pump disposed in a fluid circuit and configured to pressurize a fluid in the fluid circuit; a backup pump disposed in the fluid circuit as a redundancy to the primary pump; at least one battery sensor operable to generate a battery sensor signal representative of a condition of the vehicle battery; and a controller operatively coupled with the at least one battery sensor, the controller including a processor, a memory device operatively coupled with the processor, and battery load test logic stored in the memory device and being executable via the processor to determine health of the vehicle battery by: (i) initiating a current draw on the vehicle battery by the backup pump, (ii) receiving the battery sensor signal, and (iii) determining the battery health based on the battery sensor signal.
2. The onboard battery load test system of claim 1, wherein initiating the current draw occurs while the utility vehicle is running.
3. The onboard battery load test system of claim 1, wherein the backup pump is a hydraulic pump.
4. The onboard battery load test system of claim 1, wherein the fluid circuit is a hydraulic steering circuit, the primary pump is a primary steering pump, and the backup pump is a backup steering pump.
5. The onboard battery load test system of claim 1, wherein the condition of the vehicle battery includes one or more of a battery current, a battery voltage, or a battery temperature.
6. The onboard battery load test system of claim 1, wherein the condition of the vehicle battery includes a battery current, a battery voltage, and a battery temperature.
7. The onboard battery load test system of claim 1, wherein determining the battery health includes tracking battery sensor signals over time.
8. The onboard battery load test system of claim 1, wherein the condition of the vehicle battery includes battery temperature, and wherein determining the battery health is based on the battery temperature.
9. The onboard battery load test system of claim 1, further comprising an alternator configured to charge the vehicle battery, wherein the battery load test logic is executable by the processor to determine health of the vehicle battery further by isolating the vehicle battery from the alternator charge current.
10. The onboard battery load test system of claim 1, wherein initiating current draw on the vehicle battery by the backup pump includes closing a backup pump relay to establish an electrical connection between the vehicle battery and the backup pump.
11. The onboard battery load test system of claim 1, wherein the battery load test logic stored in the memory device is further executable by the processor to generate a test output signal based on the battery health.
12. An onboard battery load test system for a utility vehicle, the onboard battery load test system comprising: a vehicle battery onboard the utility vehicle; at least one battery sensor onboard the utility vehicle, the at least one battery sensor configured to generate signals representative of battery current, battery voltage, and battery temperature; and a controller operatively coupled with the at least one battery sensor, the controller including a processor, a memory device operatively coupled with the processor, and battery load test logic stored in the memory device and being executable via the processor to determine health of the vehicle battery by: (i) initiating a current draw on the vehicle battery, (ii) receiving the battery current, battery voltage, and battery

temperature signals during the current draw, and (iii) determining the battery health based on the battery current, battery voltage, and battery temperature signals.
13. The onboard battery load test system of claim 11, wherein the current draw is at least 10% of a cold cranking amp (CCA) rating of the vehicle battery.
14. The onboard battery load test system of claim 11, wherein determining the battery health includes calculating battery internal resistance based on the battery current and battery voltage.
15. The onboard battery load test system of claim 11, wherein determining the battery health includes tracking battery sensor signals over time.
16. The onboard battery load test system of claim 11, wherein the battery current, battery voltage, and battery temperature are stored remotely from the utility vehicle.
17. The onboard battery load test system of claim 11, further comprising a remote operations center configured to receive and store battery sensor signals from a fleet of utility vehicles, wherein determining the battery health further includes analyzing battery sensor signals from the fleet of utility vehicles.
18. The onboard battery load test system of claim 11, wherein the battery load test logic stored in the memory device is further executable by the processor to generate a test output signal based on the battery health.
19. A method for conducting an onboard battery load test to determine health of a vehicle battery in a utility vehicle, the method comprising: generating, by at least one onboard battery sensor, a battery sensor signal representative of a condition of the vehicle battery; and executing, via a processor of a controller, battery load test logic stored in a memory device of the controller to determine health of the vehicle battery by: (i) initiating a current draw on the vehicle battery, (ii) receiving the battery sensor signal during the current draw, and (iii) determining the battery health based on the battery sensor signal.
20. The method of claim 19, wherein the utility vehicle has a primary pump disposed in a pressurizeable fluid circuit and a backup pump disposed in the fluid circuit as a redundancy to the primary pump, and wherein the backup pump includes a backup hydraulic steering pump, and wherein the battery sensor signal includes signals representative of vehicle battery current, vehicle battery voltage, and vehicle battery temperature.