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Battery health self-test protocol

Abstract

Provided are embodiments for a system and method for performing a battery health self-test protocol. The embodiments can include detecting a transport refrigeration unit (TRU) is connected to standby power, and charging the battery to a known charge level during a charge cycle. Embodiments can also include discharging the battery during a discharge cycle by coupling the battery to a battery test resistor, and calculating battery health assessment information for the battery.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application claims the benefit of U.S. Provisional Application No. 63/141,531 filed Jan. 26, 2021, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND
(1) The present disclosure relates to battery technologies, and more specifically, to a battery health self-test protocol for transport refrigeration units (TRU).
(2) Truck trailers used to transport perishable and frozen goods include a refrigerated trailer pulled behind a truck cab unit. The refrigerated trailer, which houses the perishable or frozen cargo, requires a refrigeration unit for maintaining a desired temperature environment within the interior volume of the container. The refrigeration unit must have sufficient refrigeration capacity to maintain the product stored within the trailer at the desired temperature over a wide range of ambient air temperatures and load conditions. Refrigerated trailers of this type are used to transport a wide variety of products, ranging for example from freshly picked produce to deep frozen seafood. Product may be loaded into the trailer unit directly from the field, such as freshly picked fruits and vegetables, or from a warehouse.
BRIEF DESCRIPTION
(3) According to an embodiment, a method for performing a battery health self-test protocol is provided. The method can include detecting, using a controller, that a transport refrigeration unit (TRU) is connected to standby power; and charging the battery to a known charge level during a charge cycle. The method can also include discharging the battery during a discharge cycle by coupling the battery to a battery test resistor; and calculating battery health assessment information for the battery.
(4) In addition to one or more of the features described herein, or as an alternative, further

embodiments include recharging the battery to a full charge level.
(5) In addition to one or more of the features described herein, or as an alternative, further embodiments include using the standby power that is provided from a power grid, and detecting the TRU is plugged into the power grid.
(6) In addition to one or more of the features described herein, or as an alternative, further embodiments include recharging the battery using the standby power from a power grid.
(7) In addition to one or more of the features described herein, or as an alternative, further embodiments include recharging the battery using only the standby power from the power grid while a generator of the TRU is not in operation.
(8) In addition to one or more of the features described herein, or as an alternative, further embodiments include providing a prompt to connect the battery to the standby power if the standby power is not detected.
(9) In addition to one or more of the features described herein, or as an alternative, further embodiments include using a known charge level that is less than a fully charged state of the battery.
(10) In addition to one or more of the features described herein, or as an alternative, further embodiments include charging the battery using a generator of the TRU during the charging cycle.
(11) In addition to one or more of the features described herein, or as an alternative, further embodiments include receiving the battery information including an age and capacity of the battery, wherein the battery information is used to calculate the battery health assessment information.
(12) In addition to one or more of the features described herein, or as an alternative, further embodiments include outputting the battery health assessment information to a display.
(13) According to another embodiment, a system for performing a battery health self-test protocol is provided. The system can include a battery coupled to a transport refrigeration unit (TRU), and a controller coupled to the battery. The controller is configured to detect the TRU is connected to standby power; and charge the battery to a known charge level during a charge cycle. The controller can be configured to discharge the battery during a discharge cycle by coupling the battery to a battery test resistor; and calculate battery health assessment information for the battery.
(14) In addition to one or more of the features described herein, or as an alternative, further embodiments include a controller that is further configured to recharge the batter to a full charge level
(15) In addition to one or more of the features described herein, or as an alternative, further embodiments include using the standby power that is provided from a power grid, and detecting the TRU is plugged into the power grid.
(16) In addition to one or more of the features described herein, or as an alternative, further embodiments include recharging the battery using the standby power from a power grid.
(17) In addition to one or more of the features described herein, or as an alternative, further embodiments include recharging the battery using only the standby power from the power grid while a generator of the TRU is not in operation.
(18) In addition to one or more of the features described herein, or as an alternative, further embodiments include a controller that is further configured to provide a prompt to connect the battery to the standby power if the standby power is not detected.
(19) In addition to one or more of the features described herein, or as an alternative, further embodiments include using a known charge level that is less than a fully charged state of the battery.
(20) 18. In addition to one or more of the features described herein, or as an alternative, further embodiments include charging the battery using a generator of the TRU during a charging cycle.
(21) In addition to one or more of the features described herein, or as an alternative, further embodiments include a controller that is configured to receive the battery information including an age and capacity of the battery, wherein the battery information is used to calculate the battery

health assessment information.
(22) In addition to one or more of the features described herein, or as an alternative, further embodiments include a display to output the battery health assessment information.
(23) Technical effects of embodiments of the present disclosure include performing a self-test for a battery which enables the battery to be replaced on an as-needed basis instead of a prescribed schedule which may replace a battery having some remaining useful life or not replace a battery that is exhibiting premature failure.
(24) The foregoing features and elements may be combined in various combinations without exclusivity, unless expressly indicated otherwise. These features and elements as well as the operation thereof will become more apparent in light of the following description and the accompanying drawings. It should be understood, however, that the following description and drawings are intended to be illustrative and explanatory in nature and non-limiting.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:
(2) FIG. **1** depicts a schematic illustration of a transport refrigeration unit (TRU) capable of performing a battery health self-test protocol in accordance with one or more embodiments;
(3) FIG. **2** depicts a flowchart of a method for performing a battery health self-test protocol in accordance with one or more embodiments; and
DETAILED DESCRIPTION
(4) Referring now to FIG. **1**, there is shown schematically, an exemplary embodiment of a truck trailer refrigeration system **100** including an engine **110**, an electric generator **120** operatively associated with the engine **110**, a system controller **130**, a power input selector **140** and a transport refrigeration unit **10** (commonly referred to as a “TRU”). Also shown in FIG. **1**, the engine **110** is coupled to the TRU start battery **150** (hereinafter referred to as the “battery **150**”), and the battery charger **160** is coupled to the controller **130** and the battery **150**. The transport refrigeration unit **10** described herein may function to regulate and maintain a desired product storage temperature range within a refrigerated volume wherein a perishable or frozen product is stored during transport, such as a refrigerated box of a trailer. As shown, the transport refrigeration unit **10** may include a compressor **20**, a condenser heat exchanger unit **30** including a condenser heat exchange coil **32** and associated condenser fan **34** and fan motor **36** assembly, an evaporator heat exchanger unit **40** including an evaporator heat exchanger coil **42** and associated evaporator fan **44** and fan motor **46** assembly, and an evaporator expansion device **50**, such as an electronic expansion valve (EXV) or a thermostatic expansion valve (TXV), connected in a conventional refrigeration cycle by refrigerant lines **2**, **4** and **6** in a refrigerant flow circuit. The condenser heat exchanger unit **30** may also include a subcooling coil **38** disposed in series refrigeration flow relationship with and downstream of the primary condenser heat exchange coil **32**. In addition, the refrigeration system can also include other components that are known to be associated with refrigeration systems such as, sensors, other expansion devices, other types of heat exchangers, valves, thermostats, receivers, filter driers, etc.
(5) Now referring to FIG. **2**, a flowchart of a method **200** for performing the battery health self-test in accordance with one or more embodiments is shown. It should be understood the method **200** can be implemented in any suitable system, such as the system **100** shown in FIG. **1** (although other suitable systems may be used to implement the method **200** in certain instances). The method **200** begins and proceeds to block **202** to initiate the battery health self-test (referred to herein as “self-test”). In one or more embodiments, the self-test can be automatically performed according to

a schedule. In different embodiments, the self-test can be performed when a manual selection is provided and input to the controller **130**.

(6) At decision block **204**, the controller **130** determines whether the TRU is connected to standby power such as the power from the power grid (which may be connected using a plug **170** or other suitable connection, as shown in FIG. **1**). In one or more embodiments, the controller **130** can use a voltage sensor/current sensor to determine if the TRU is coupled to the standby power. The standby power can be an external power source such as a power grid (AC power). As mentioned above, the TRU may be designed to be plugged into an outlet to receive the standby power which allows the charging of the battery **150** or provide a supply of power for other operations. In the event the TRU is not connected to the standby power ("No" branch), a message can be provided on a display of an interface to plug in the TRU at **206**. The method **200** then returns to block **204** to determine if the TRU has been connected to the standby power.

(7) If the TRU is connected to the standby power ("Yes" branch), the method **200** proceeds to block **208** and displays a message to retrieve the battery information. In some embodiments, the battery information can be retrieved automatically from one or more sources the controller **130** may have access to such as a battery/power system, a diagnostic system (e.g., onboard diagnostic system (ODB)), or another type of TRU-related system. In other embodiments, the battery information can be manually input by an operator (block **210**) and provided to the controller **130** and used for battery calculations. The battery information can include but is not limited to the battery age and capacity. It should be understood that additional information can be retrieved and input into the controller **130** to perform the self-test and is not intended to be limited by that shown in FIG. **2**.

(8) The method **200** continues to block **212** and starts the self-test and proceeds to block **214** which operates the TRU to charge the battery **150** (either fully or partially). In one or more embodiments, an engine **110** that converts fuel to mechanical energy to drive a generator **120** of the TRU is used to generate power to charge the battery to a known level to perform the self-test. In some embodiments, the charge level of the battery **150** is charged to a known level that is less than a fully charged level. In other embodiments, the battery can be fully charged. The source of power for the generator **120** can include a fuel-type source such as diesel. In one or more embodiments, the engine **110** of the TRU that drives the generator **120** is not in operation during the self-test.

(9) At block **216**, the controller **130** checks the voltage and charge time of the battery **150**. If the expected voltage level and charge time are not met, the TRU continues to charge the battery to the expected level. If the voltage level and charge time are met ("Yes" branch), the method **200** proceeds to block **218** which runs a battery rest interval to settle the battery. The rest interval allows the charge level of the battery to settle at a voltage level and minimize the fluctuations in voltage resulting from charging so that an accurate test can be performed. At block **220**, the controller **130** determines whether the battery has settled during the rest interval. In a non-limiting example, the battery can be determined to be settled if the voltage level is within a margin. If not ("No" branch) the method **200** returns to block **218** to run/continue the battery rest interval.

(10) If the battery **150** has settled ("Yes" branch), the method **200** continues to block **222** and runs the battery drain interval (which may be referred to as the discharge cycle). During the battery drain interval a known load (i.e., a battery test resistor) is connected to the battery **150** to discharge the battery **150**. At decision block **224**, the battery drain interval is checked to see if it is completed. In one or more embodiments, the battery drain interval is completed responsive to reaching a predetermined or known discharge level. In other embodiments, the battery drain interval can be completed responsive to the expiration of a period of time. If the battery drain interval is not completed ("No" branch), the method **200** returns to block **222** to run/continue to battery drain interval (i.e., the discharge cycle).

(11) Upon completion of the discharge cycle, the known load is electrically disconnected from the battery **150** to stop the discharging of the battery **150** and various battery measurements can be taken. The method **200** proceeds to block **226** to start the recharge cycle for the battery **150** and

calculate the battery health assessment information. At block **228**, the battery health assessment information can be output to a display.
(12) In one or more embodiments, the battery recharge cycle only uses the wall power/grid power to recharge the battery **150**. In these instances, the engine **110** and generator are not required to recharge the battery **150** immediately after performing the self-test. At decision block **230**, the controller **130** determines whether the battery **150** has been fully recharged using the standby power. If not (“No” branch), the method **200** proceeds to block **232** to continue to recharge the battery **150**. If the battery **150** is fully recharged (“Yes” branch), the method **200** proceeds to block **234**, and the method **200** ends. The method **200** can be repeated at a scheduled time or upon manual initiation by an operator. It should be understood that a different sequence of steps or additional steps can be used.
(13) The techniques described herein enable testing of the battery while the system is not in operation. Conventional systems are required to remain in operation to perform a battery health test. The battery can be tested and recharged to full capacity without operator intervention using the techniques described herein. The techniques described herein allow the batteries to be replaced on an as-needed basis as opposed to a prescribed maintenance schedule where usable life remains in the battery.
(14) A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.
(15) The term “about” is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application.
(16) The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present 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 terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.
(17) While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

Claims

1. A method for performing a battery health self-test protocol for a battery, the method comprising: detecting, using a controller, that a transport refrigeration unit (TRU) is connected to standby power; charging the battery to a known charge level during a charge cycle; discharging the battery during a discharge cycle by coupling the battery to a battery test resistor; and calculating battery health assessment information for the battery; wherein the standby power is provided from a power grid; wherein the detecting, charging, discharging and calculating occur in response to the TRU being plugged into the power grid.
2. The method of claim 1, further comprising recharging the battery to a full charge level.
3. The method of claim 2, wherein recharging the battery comprises using the standby power from a power grid.
4. The method of claim 3, wherein recharging the battery comprises only using the standby power

from the power grid while a generator of the TRU is not in operation.
5. The method of claim 1, further comprising providing a prompt to connect the battery to the standby power if the standby power is not detected.
6. The method of claim 1, wherein the known charge level is less than a fully charged state of the battery.
7. The method of claim 1, wherein the charge cycle comprises charging the battery using a generator of the TRU.
8. The method of claim 1, further comprising receiving the battery information comprising age and capacity of the battery, wherein the battery information is used to calculate the battery health assessment information.
9. The method of claim 8, further comprising outputting the battery health assessment information to a display.
10. The method of claim 1, wherein the battery comprises a TRU start battery.
11. A system for performing a battery health self-test protocol, the system comprising: a battery coupled to a transport refrigeration unit (TRU); and a controller coupled to the battery, wherein the controller is configured to: detect the TRU is connected to standby power; charge the battery to a known charge level during a charge cycle; discharge the battery during a discharge cycle by coupling the battery to a battery test resistor; and calculate battery health assessment information for the battery; wherein the standby power is provided from a power grid; wherein the detecting, charging, discharging and calculating occur in response to the TRU being plugged into the power grid.
12. The system of claim 11, wherein the controller is further configured to recharge the battery to a full charge level.
13. The system of claim 12, wherein recharging the battery comprises using the standby power from a power grid.
14. The system of claim 13, wherein recharging the battery comprises only using the standby power from the power grid while a generator of the TRU is not in operation.
15. The system of claim 11, wherein the controller is further configured to provide a prompt to connect the battery to the standby power if the standby power is not detected.
16. The system of claim 11, wherein the known charge level is less than a fully charged state of the battery.
17. The system of claim 11, wherein the charge cycle comprises charging the battery using a generator of the TRU.
18. The system of claim 11, wherein the controller is further configured to receive the battery information comprising age and capacity of the battery, wherein the battery information is used to calculate the battery health assessment information.
19. The system of claim 18, further comprising a display to output the battery health assessment information.