United States Patent Application Publication	20250264546
Kind Code	A1
Publication Date	August 21, 2025
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Battery Abnormality Diagnosis Apparatus and Operating Method Thereof

Abstract

A battery abnormality diagnosis apparatus includes an obtaining unit configured to obtain voltage-state-of-charge (SOC) profiles of a plurality of battery units, an identifying unit configured to identify a designated first number of ranks of each of the plurality of battery units, based on the voltage-SOC profiles, and a diagnosing unit configured to diagnose abnormality of the plurality of battery units, based on changes of the ranks.

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Appl. No.: **19/202769**

Filed: **May 08, 2025**

Foreign Application Priority Data

KR	10-2022-0151062	Nov. 11, 2022

Related U.S. Application Data

parent WO continuation-in-part PCT/KR2023/017957 20231109 PENDING child US 19202769

Publication Classification

Int. Cl.: **G01R31/392** (20190101); **G01R19/00** (20060101); **G01R31/371** (20190101); **G01R31/3842** (20190101); **G01R31/396** (20190101)

U.S. Cl.:

CPC **G01R31/392** (20190101); **G01R19/003** (20130101); **G01R31/371** (20190101); **G01R31/3842** (20190101); **G01R31/396** (20190101);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] The present application is a by-pass continuation-in-part of International Application No. PCT/KR2023/017957, filed on Nov. 9, 2023, which claims priority from Korean Patent Application No. 10-2022-0151062, filed on Nov. 11, 2022, all of which are hereby incorporated herein by reference in their entireties.

TECHNICAL FIELD
[0002] Embodiments disclosed herein relate to a battery abnormality diagnosis apparatus and an operating method thereof.
BACKGROUND
[0003] Recently, research and development of secondary batteries have been actively performed. Herein, the secondary batteries, which are chargeable/dischargeable batteries, may include all of conventional nickel (Ni)/cadmium (Cd) batteries, Ni/metal hydride (MH) batteries, etc., and recent lithium-ion batteries. Among the secondary batteries, a lithium-ion battery has a much higher energy density than those of the conventional Ni/Cd batteries, Ni/MH batteries, etc. Moreover, the lithium-ion battery may be manufactured to be small and lightweight, such that the lithium-ion battery has been used as a power source of mobile devices. In addition, the lithium ion battery is attracting attention as a next-generation energy storage medium as a usage range thereof is expanded to a power source of electric vehicles.
[0004] Furthermore, the secondary battery may be used as a battery pack including a battery module where a plurality of battery cells are connected to one another in series and/or in parallel. The secondary battery may be used as a battery rack including a plurality of battery modules and a rack frame receiving the battery modules.
[0005] The battery cell, the battery module, the battery pack, or the battery rack may be used in various devices. For example, the batteries may be used not only for mobile devices such as mobile phones, laptop computers, smart phones, smart pads, etc., but also in the field of vehicles (EV, HEV, PHEV) driven with electricity, large-volume energy storage systems (ESS), etc.
[0006] These batteries may be managed and controlled in terms of states and operations thereof by a battery management system (BMS). The battery management system may be included together with a battery in one device. The battery management system may also manage and control the battery in a state of being spaced apart from a device including the battery.
SUMMARY OF THE INVENTION
Technical Problem
[0007] When a short circuit or a failure of another type occurs inside a battery, the possibility of damage to devices (e.g., EV, ESS) including the battery may increase.
[0008] Accordingly, there is a need for a scheme to reduce the possibility of damage to devices including a battery by detecting an abnormal state of the battery.
[0009] Technical problems of the embodiments disclosed herein are not limited to the above-described technical problems, and other unmentioned technical problems would be clearly understood by one of ordinary skill in the art from the following description.

Technical Solution

[0010] A battery abnormality diagnosis apparatus according to an embodiment disclosed herein includes a processor; and memory having programmed thereon instructions, wherein the instructions are configured to cause the processor to for each battery unit of the plurality of battery units obtain a respective voltage-state-of-charge (SOC) profile of the battery unit, wherein the respective voltage-SOC profile includes state-of-charge information for each of a plurality of charging cycles of the battery and a plurality of discharging cycles of the battery, for each battery unit of the plurality of battery units, identify a ranking of the battery unit among the plurality of battery units for each of the charging cycles and each of the discharging cycles included in the respective voltage-SOC profile, based on the state-of-charge information included in the respective voltage-SOC profile, and diagnose abnormality of the plurality of battery units, based on changes of the identified rankings.

[0011] In an embodiment, each SOC voltage profile may include a plurality of SOC periods and the instructions may be configured to cause the processor to for each battery unit of the plurality of battery units, for two or more SOC periods of the voltage SOC profile, identify a representative voltage value of the SOC period, whereby, for each SOC period of the two or more SOC periods, the ranking of the battery unit at the SOC period may be based on the respective representative voltage value of the battery unit for the SOC period.

[0012] In an embodiment, the instructions may be configured to cause the processor to for each battery unit of the plurality of battery units, for each SOC period of the two or more SOC periods, set the representative voltage value of the SOC period equal to an average value of voltage values of the battery unit for the SOC period.

[0013] In an embodiment, the instructions may be configured to cause the processor to diagnose at least one battery unit of the plurality of battery units as abnormal based on fulfillment of a first condition during charging or a second condition during discharging, wherein the second condition is different than the first condition, and wherein each of the first condition and the second condition relates to the ranking of the at least one battery unit changing by a reference value or greater over time.

[0014] In an embodiment, the reference value may be a function of a total number of the plurality of battery units.

[0015] In an embodiment, the first condition may be the ranking of the at least one battery unit increasing by the reference value or greater during charging and the second condition may be the ranking of the at least one battery unit decreasing by the reference value or greater during discharging.

[0016] In an embodiment, the instructions may be configured to cause the processor to obtain the voltage-SOC profiles of the plurality of battery units through an external electronic device connected to the battery abnormality diagnosis apparatus through a wired and/or wireless network.

[0017] In an embodiment, the instructions may be configured to cause the processor to for each battery unit of the plurality of battery units read a voltage, a current, a temperature, or a combination thereof from the battery unit and generate the respective voltage-SOC profile of the battery unit based on the read voltage, current, temperature, or combination thereof.

[0018] In an embodiment, the plurality of battery units may include one of a battery cell, a battery module, a battery pack, or a battery rack.

[0019] In an embodiment, the instructions may be configured to cause the processor to perform an abnormality processing function based on an abnormality diagnosis result of the plurality of battery units, in which the abnormality processing function includes a notification function or an isolation function.

[0020] An operating method of a battery abnormality diagnosis apparatus according to an embodiment disclosed herein includes for each battery unit of the plurality of battery units, obtaining a voltage-state-of-charge (SOC) profile of the battery unit, for each battery unit of the plurality of battery units, identifying a ranking of the battery unit among the plurality of battery units based on the respective voltage-SOC profile, and diagnosing abnormality of the plurality of battery units, based on changes of the identified rankings over time.

[0021] In an embodiment, each SOC voltage profile may include a plurality of SOC periods, and the method may include for each battery unit of the plurality of battery units, for two or more SOC periods of the voltage SOC profile, identifying a representative voltage value of the SOC period, whereby identifying the ranking of the battery unit comprises, for each SOC period of the two or more SOC periods, identifying the ranking of the battery unit at the SOC period based on the respective representative voltage value of the battery unit for the SOC period.

[0022] In an embodiment, the method may include for each battery unit of the plurality of battery units, for each SOC period of the two or more SOC periods, setting the representative voltage value of the SOC period equal to an average value of voltage values of the battery unit for the SOC period.

[0023] In an embodiment, the diagnosing may include diagnosing at least one battery unit of the plurality of battery units as abnormal based on fulfillment of a first condition during charging or a second condition during discharging, wherein the second condition is different than the first condition, and wherein each of the first condition and the second condition relates to the ranking of the at least one battery changing by a reference value or greater over time.

[0024] In an embodiment, the reference value may be a function of a total number of the plurality of battery units.

[0025] In an embodiment, the first condition may be the ranking of the at least one battery unit increasing by the reference value or greater during charging and the second condition may be the ranking of the at least one battery unit decreasing by the reference value or greater during discharging.

[0026] In an embodiment, the obtaining may be performed through an external electronic device connected to the battery abnormality diagnosis apparatus through a wired and/or wireless network.

[0027] In an embodiment, the obtaining may include for each battery unit of the plurality of battery units reading a voltage, a current, a temperature, or a combination thereof from the battery unit and generating the respective voltage-SOC profile of the battery unit based on the read voltage, current, temperature, or combination thereof.

[0028] In an embodiment, the plurality of battery units may include one of a battery cell, a battery module, a battery pack, or a battery rack.

[0029] In an embodiment, the operating method may further include performing an abnormality processing function based on an abnormality diagnosis result of the plurality of battery units, in which the abnormality processing function includes a notification function or an isolation function.

Advantageous Effects

[0030] A battery abnormality diagnosis apparatus and an operating method thereof according to various embodiments disclosed herein may detect occurrence of a short circuit or a failure of another type inside a battery.

[0031] A battery abnormality diagnosis apparatus and an operating method thereof according to various embodiments disclosed herein may process the detected short circuit or failure of another type inside the battery.

[0032] The effects of the battery abnormality diagnosis apparatus and the operating method thereof according to the disclosure of the present document are not limited to the effects mentioned above, and other effects not mentioned will be clearly understood by those of ordinary skill in the art according to the disclosure of the present document.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] FIG. **1** show graphs of voltage-state-of-charge (SOC) profiles.

[0034] FIG. **2** illustrates a battery abnormality diagnosis apparatus according to an embodiment of the present disclosure.

[0035] FIG. **3** illustrates a voltage-SOC profile.

[0036] FIG. **4** is a flowchart showing an operating method of a battery abnormality diagnosis apparatus according to an embodiment of the present disclosure.

[0037] FIG. **5** is a flowchart showing an operating method of a battery abnormality diagnosis apparatus according to an embodiment of the present disclosure.

[0038] With regard to the description of the drawings, similar reference numerals may be used to refer to similar or related components.

DETAILED DESCRIPTION

[0039] Hereinafter, embodiments of the present disclosure will be described with reference to the accompanying drawings. However, the description is not intended to limit the present disclosure to particular embodiments, and it should be construed as including various modifications, equivalents, and/or alternatives according to the embodiments of the present disclosure.

[0040] It should be appreciated that embodiments of the present document and the terms used therein are not intended to limit the technological features set forth herein to a particular embodiment and include various changes, equivalents, or replacements for a corresponding embodiment. With regard to the description of the drawings, similar reference numerals may be used to refer to similar or related elements. It is to be understood that a singular form of a noun corresponding to an item may include one or more of the things, unless the relevant context clearly indicates otherwise.

[0041] As used herein, each of such phrases as "A or B," "at least one of A and B," "at least one of A or B," "A, B, or C," "at least one of A, B, and C," and "at least one of A, B, or C," may include any one of, or all possible combinations of the items enumerated together in a corresponding one of the phrases. Such terms as "1.sup.st", "2.sup.nd," "first", "second", "A", "B", "(a)", or "(b)" may be used to simply distinguish a corresponding component from another, and does not limit the components in other aspect (e.g., importance or order), unless mentioned otherwise.

[0042] Herein, it is to be understood that when an element (e.g., a first element) is referred to, with or without the term "operatively" or "communicatively", as "connected with", "coupled with", or "linked with", or "coupled to" or "connected to" to another element (e.g., a second element), it means that the element may be connected with the other element directly (e.g., wiredly or wirelessly), or indirectly (e.g., via a third element).

[0043] A method according to various embodiments disclosed herein may be included and provided in a computer program product. The computer program product may be traded as a product between a seller and a buyer. The computer program product may be distributed in the form of a machine-readable storage medium (e.g., compact disc read only memory (CD-ROM)), or be distributed (e.g., downloaded or uploaded) online via an application store, or between two user devices directly. If distributed online, at least part of the computer program product may be temporarily generated or at least temporarily stored in the machine-readable storage medium, such as memory of the manufacturer's server, a server of the application store, or a relay server.

[0044] According to embodiments disclosed herein, each component (e.g., a module or a program) of the above-described components may include a single entity or multiple entities, and some of the multiple entities may be separately disposed in different components. According to various embodiments disclosed herein, one or more of the above-described components may be omitted, or one or more other components may be added. Alternatively or additionally, a plurality of components (e.g., modules or programs) may be integrated into a single component. In such a case, according to various embodiments, the integrated component may still perform one or more functions of each of the plurality of components in the same or similar manner as they are performed by a corresponding one of the plurality of components before the integration. According to embodiments disclosed herein, operations performed by the module, the program, or another component may be carried out sequentially, in parallel, repeatedly, or heuristically, or one or more of the operations may be executed in a different order or omitted, or one or more other operations may be added.

[0045] FIG. **1** show graphs that graphically illustrate the data contained in voltage-state-of-charge (SOC) profiles. Referring to FIG. **1**, a voltage-SOC profile graph **10** showing data representing a normal behavior **11** and a deterioration behavior **15** of a battery unit, a voltage-SOC profile graph **20** showing data representing the normal behavior **11** and an abnormal behavior **25** of a battery unit, and a voltage-SOC profile graph **30** showing data representing the normal behavior **11** and an abnormal behavior **35** of the battery unit may be seen. Damage to an electronic device may occur due to the battery unit showing the abnormal behavior. Thus, a battery unit having an abnormal behavior may be detected from among battery units, and may need to be appropriately processed.

[0046] FIG. **2** is a block diagram of a battery abnormality diagnosis apparatus **101** according to an embodiment of the present disclosure. FIG. **3** is a view **310** showing a voltage-SOC profile **311**.

[0047] Referring to FIG. **2**, the battery abnormality diagnosis apparatus **101** may be wiredly and/or wirelessly connected to an electronic device **103** and a user terminal **105**.

[0048] In an embodiment, connection **104** between the battery abnormality diagnosis apparatus **101** and the electronic device **103** may be communication connection through a wired and/or wireless network. In an embodiment, the wired network may be based on a local area network (LAN) communication or a power-line communication. In an embodiment, the wireless network may be based on a short-range communication network (e.g., Bluetooth, Wireless Fidelity (WiFi), or Infrared Data Association (IrDA)) or a remote-range communication network (e.g., a cellular network, a 4.sup.th-Generation (4G) network, a 5.sup.th-Generation (5G) network).

[0049] In another embodiment, the connection **104** between the battery abnormality diagnosis apparatus **101** and the electronic device **103** may be connection using a device-to-device communication scheme (e.g., a bus, a general-purpose input and output (GPIO), a serial peripheral interface (SPI), or a mobile industry processor interface (MIPI)).

[0050] In an embodiment, connection **106** between the battery abnormality diagnosis apparatus **101** and the user terminal **105** may be communication connection through a wired and/or wireless network.

[0051] In an embodiment, the electronic device **103** may be a mobile device (e.g., a mobile phone, a laptop computer, a smart phone, a smart pad), an electric vehicle (e.g., an electric vehicle (EV), a hybrid EV (HEV), a plug-in HEV (PHEV), a fuel cell EV (FCEV)), an energy storage system (ESS), or a battery swapping system (BSS).

[0052] In an embodiment, the electronic device **103** may include one or more battery units **111**, **113**, and **115**. Each of the one or more battery units **111**, **113**, and **115** may be a battery cell, a battery module, a battery pack, or a battery rack.

[0053] In an embodiment, the user terminal **105** may be a mobile device (e.g., a mobile phone, a laptop computer, a smart phone, a smart pad), or a personal computer (PC).

[0054] In an embodiment, the battery abnormality diagnosis apparatus **101** may include a communication circuit **120**, a sensor **130**, a memory **140**, and a processor **150**. According to an embodiment, the battery abnormality diagnosis apparatus **101** shown in FIG. **2** may further include at least one component (e.g., a display, an input device, or an output device) in addition to components shown in FIG. **2**.

[0055] In an embodiment, the communication circuit **120** may establish a wired communication channel and/or a wireless communication channel between the battery abnormality diagnosis apparatus **101** and the electronic device **103** and/or the user terminal **105**, and transmit and receive data to and from the electronic device **103** and/or the user terminal **105** through the established

communication channel.
[0056] In an embodiment, the sensor **130** may obtain values related to states of the battery units **111**, **113**, and **115** of the electronic device **103**. In an embodiment, the values related to the states may indicate one or more values of voltages, currents, resistances, SOC, states of health (SOH), or temperatures of the battery units **111**, **113**, and **115** or combinations thereof. Hereinbelow, the value related to the state may be referred to as a ‘state value’.
[0057] In an embodiment, the memory **140** may include a volatile and/or a nonvolatile memory.
[0058] In an embodiment, the memory **140** may store data used by at least one component (e.g., the processor **150**) of the battery state estimation apparatus **100**. For example, the data may include software (or an instruction related thereto), input data, or output data. In an embodiment, the instruction, when executed by the processor **150**, may cause the battery abnormality diagnosis apparatus **101** to perform operations defined by the instruction.
[0059] In an embodiment, the memory **140** may include one or more software (e.g., an obtaining unit **141**, an identifying unit **143**, a diagnosing unit **145**, and an abnormality processing unit **147**).
[0060] In an embodiment, the processor **150** may include a central processing unit, an application processor, a graphic processing unit, a neural processing unit (NPU), an image signal processor, a sensor hub processor, or a communication processor.
[0061] In an embodiment, the processor **150** may execute various programs stored in the memory **140**, including but not limited to the obtaining unit **141**, the identifying unit **143**, the diagnosing unit **145**, and the abnormality processing unit **147**. The software programs may be executed to control other hardware components, software components, or both, to perform various data processing or operations. One or more of the hardware and/or software components may be included within the battery diagnosis apparatus **101** that includes the processor **150**. Additionally or alternatively, one or more of the hardware and/or software components may be situated remotely from, but communicatively connected to, the battery diagnosis apparatus **101**.
[0062] Hereinbelow, a description will be made of a method, performed by the battery abnormality diagnosis apparatus **101**, of diagnosing abnormality of the battery units **111**, **113**, and **115** through the obtaining unit **141**, the identifying unit **143**, the diagnosing unit **145**, and/or the abnormality processing unit **147**.
[0063] In an embodiment, the obtaining unit **141** may obtain voltage-SOC profiles of the plurality of battery units **111**, **113**, and **115**. In an embodiment, the voltage-SOC profile may indicate a relationship between an SOC of a battery unit (e.g., the battery unit **111**) and a voltage.
[0064] In an embodiment, the obtaining unit **141** may obtain the voltage-SOC profiles of the plurality of respective battery unit **111**, **113**, and **115** through the electronic device **103** connected through a wired and/or wireless network. In another embodiment, the obtaining unit **141** may obtain voltages, currents, temperatures of the plurality of battery unit **111**, **113**, and **115**, or a combination thereof through the electronic device **103** connected through a wired and/or wireless network, and generate the voltage-SOC profiles based on the obtained voltages, currents, temperatures, or combination thereof.
[0065] In an embodiment, the obtaining unit **141** may read the voltage, current, temperature, or a combination thereof, from each of the plurality of battery unit **111**, **113**, and **115**, and generate the voltage-SOC profiles based on the read voltage, current, temperature, or combination thereof.
[0066] In an embodiment, the identifying unit **143** may identify a designated first number of ranks of each of the plurality of battery units **111**, **113**, and **115**, based on the voltage-SOC profiles. Herein, the designated first number may correspond to the number of SOC periods. Herein, the designated first number may be less than the number of SOC periods. Herein, the SOC periods may include periods for identifying an SOC during charging of the battery unit from 0% to 100%, and/or periods for identifying an SOC during discharging of the battery unit from 100% to 0%.
[0067] For example, referring to FIG. **3**, the designated first number may be 4 that is the number of SOC periods R**1**, R**2**, R**3**, and R**4** in which the battery unit is being charged. In another example,

the designated first number may be 2 that is the number of SOC periods R**1**, R**2**, R**3**, and R**4** in which the battery unit is being charged. In an embodiment, an SOC period R**1** may be a period in which an SOC is between 0% and 5%, an SOC period R**2** may be a period in which an SOC is between 5% and 25%, an SOC period R**3** is a period may be which an SOC is between 25% and 60%, and an SOC period R**4** may be a period in which an SOC is between 60% and 100%. Additionally, the designated first number may be 8 including the SOC periods R**1**, R**2**, R**3**, and R**4** in which the battery unit is being charged and SOC periods R**5**, R**6**, R**7**, and R**8** in which the battery unit is being discharged. In another example, the designated first number may be 4 that sums 2 of the SOC periods R**1**, R**2**, R**3**, and R**4** in which the battery unit is being charged and 2 of the SOC periods R**5**, R**6**, R**7**, and R**8** in which the battery unit is being discharged. In an embodiment, the SOC period R**5** may be a period in which an SOC is between 100% and 60%, the SOC period R**6** may be a period in which an SOC is between 60% and 25%, the SOC period R**7** is a period may be which an SOC is between 25% and 5%, and the SOC period R**8** may be a period in which an SOC is between 5% and 0%.

[0068] In an embodiment, the identifying unit **143** may identify ranks of the plurality of battery units **111**, **113**, and **115** in each of the first number of SOC periods among the SOC periods in which the battery unit is being charged and among the SOC periods in which the battery unit is being discharged. In an embodiment, the first number of SOC periods may be four periods, and may include two SOC periods from the SOC periods R**1**, R**2**, R**3**, and R**4** in which the battery unit is being charged and two SOC periods from the SOC periods R**5**, R**6**, R**7**, and R**8** in which the battery unit is being discharged. For example, the identifying unit **143** may identify ranks of the plurality of battery units **111**, **113**, and **115** in the SOC period R**1** during which the battery unit is being charged, ranks of the plurality of battery units **111**, **113**, and **115** in the SOC period R**4** during which the battery unit is being charged, ranks of the plurality of battery units **111**, **113**, and **115** in the SOC period R**5** during which the battery unit is being discharged, and ranks of the plurality of battery units **111**, **113**, and **115** in the SOC period R**8** during which the battery unit is being discharged. The SOC periods for which ranks of the battery units are identified may be consecutive or non-consecutive. In this regard, although examples provided herein describe ranks among non-consecutive SOC periods that extend from an SOC of 0% to an SOC of 100% or vice versa, it should be understood that the same or similar underlying principles apply even for non-consecutive SOC periods that span a narrower range of SOC values, as well as for consecutive SOC periods that span an even narrower range of SOC values. Additionally, the SOC values for the charging SOC periods for which ranks of the battery units are identified may or may not correspond to the SOC values for the discharging SOC periods for which ranks of the battery units are identified. In other words, while in the above example the SOC range of SOC period R**1** corresponds to the SOC range of SOC period R**8** and the SOC range of SOC period R**4** corresponds to the SOC range of SOC period R**5**, it should be understood that the same or similar underlying principles apply even for selected charging SOC periods for which the SOC range does not correspond to the SOC range of the selected SOC discharging periods, such as if SOC periods R**1** and R**4** were selected during charging while SOC periods R**5** and R**7** were selected during discharging.

[0069] In an embodiment, the identifying unit **143** may identify representative voltage values of the SOC periods of the first number of each of the voltage-SOC profiles and identify the ranks based on the representative voltage values. Herein, the representative voltage value may be an average value of voltage values of each of the SOC periods of the first number. Thus, the identifying unit **143** may identify the average value of the voltage values of each of the SOC periods of the first number as a representative voltage value.

[0070] For example, the identifying unit **143** may identify the average value of the voltage values of each of the SOC periods of the first number as a representative voltage value, as shown in Table 1.

TABLE-US-00001 TABLE 1 Charging Discharging Battery Unit R1 R4 R5 R8 111 3.458 4.064

3.847 3.385 113 3.492 4.074 3.858 3.431 . . . . 115 3.495 4.074 3.857 3.436

[0071] Referring to Table 1, the representative voltage values in the SOC periods R**1** and R**4** during charging of the battery unit **111** may be 3.458 and 4.064. During discharging of the battery unit **111**, the representative voltage values in the SOC periods R**5** and R**8** may be 3.847 and 3.385. For example, the identifying unit **143** may identify the ranks as shown in Table 2, based on the representative voltage values shown in Table 1.

TABLE-US-00002 TABLE 2 Charging Discharging Battery Unit R1 R4 R5 R8 111 42 42 42 42 113 27 25 23 23 . . . . 115 19 27 25 20

[0072] Referring to Table 2, the ranks in the SOC periods R**1** and R**4** during charging of the battery unit **111** may be 42 and 42. During discharging of the battery unit **111**, the ranks in the SOC periods R**5** and R**8** may be 42 and 42. In an embodiment, the diagnosing unit **145** may diagnose abnormality of the plurality of battery units **111**, **113**, and **115** based on rank changes.

[0073] For example, the identifying unit **143** may identify the rank changes as shown in Table 3, based on the ranks shown in Table 2.

TABLE-US-00003 TABLE 3 Charging Discharging Battery Unit R1-R4 R5-R8 111 0 0 113 −2 0 . . . . 115 8 −5

[0074] Referring to Table 3, the rank change between the SOC periods R**1** and R**4** during charging of the battery unit **111** may be 0. During discharging of the battery unit **111**, the rank change between the SOC periods R**5** and R**8** may be 0. As shown in Table 3, the diagnosing unit **145** may identify the rank change between the SOC periods R**1** and R**4** during charging and identify the rank change between the SOC periods R**5** and R**8** during discharging.

[0075] In an embodiment, the diagnosing unit **145** may diagnose, among the plurality of battery units **111**, **113**, and **115**, a battery unit having a rank changing by a reference value or greater, as an abnormal battery unit. Herein, the abnormal battery may include a degraded battery (or an over-degraded battery). The reference value may represent a distance between two compared rank values. The reference value may be measured in terms of an absolute distance, such as the number of rank spots that separate two rank values, or a relative distance, such as a ratio of the absolute distance to the distance between the top and bottom rank values. Stated another way, in the case on an absolute distance, the reference value may be a fixed number regardless of the number of battery units, and in the case of relative distance, the reference value may be set based on the number of plurality of battery units. For example, in the case of an absolute distance, a reference value of 200 (or any other whole number between 1 and the one less than the total number of battery cells) may be set, whereas in the case of a relative distance, a value corresponding to 90% of the number of battery units **111**, **113**, and **115** (or a rounded value, a rounded-down value, or a rounded-up value of the value corresponding to 90%, or some other percentage or rounded approximation of that percentage) may be set to the reference value. For example, when the number of battery units **111**, **113**, and **115** is 238, the reference value may then be 200 (for absolute distance) or 214 (for relative distance). In another example, when the number of battery units **111**, **113**, and **115** is 196, for absolute distance the reference value may be something less than 196 such as 160, and for relative distance the reference value may be 176. For relative distance, percentages other than 90% may be chosen in other example implementations. Additionally, the particular absolute distance or percentage that is chosen for the reference value may relate to a known amount of variation between SOC periods that is expected for the battery unit's type, such as the amount of variation observed during testing or previous operation of the battery unit type.

[0076] In an embodiment, the diagnosing unit **145** may diagnose, among the plurality of battery units **111**, **113**, and **115**, a battery unit having a rank increasing by the reference value or greater or decreasing by the reference value or greater, as the abnormal battery unit. In an embodiment, the diagnosing unit **145** may diagnose, as the abnormal battery unit, at least one battery unit having the ranks increasing by the reference value or greater during charging or decreasing by the reference value or greater during discharging, among the plurality of battery units.

[0077] For example, when the reference value is 4, the battery unit **115** of Table 3 has a rank increase of 8 between the rank of the SOC period R**1** and the rank of the SOC period R**4** such that the diagnosing unit **145** may diagnose the battery unit **115** as the abnormal battery unit. For further example, the battery unit **115** of Table 3 has a rank decrease of −5 between the rank of the SOC period R**5** and the rank of the SOC period R**8**, such that the diagnosing unit **145** may diagnose the battery unit **115** as the abnormal battery unit. Either one of the rank increase between R**1** and R**4** or the rank decrease between R**5** and R**8** may be sufficient to diagnose the battery unit as being abnormal. In some examples, a battery unit, such as battery unit **115** of Table 3, that exhibits both a rank increase and a rank decrease that is greater than the reference value may be diagnosed as the abnormal battery.

[0078] In an embodiment, the abnormality processing unit **147** may perform an abnormality processing function based on abnormality diagnosis results for the plurality of battery units **111**, **113**, and **115**. In an embodiment, the abnormality processing function may include a notification function or a short circuit function.

[0079] For example, in performing the notification function, the abnormality processing unit **147** may transmit a notification containing the abnormality diagnosis results of the plurality of battery units **111**, **113**, and **115** to the user terminal **105** connected through a wired and/or wireless network.

[0080] In another embodiment, in performing the short circuit function, the abnormality processing unit **147** may respond to the detected presence of a short circuit by performing an isolation function that isolates the abnormality battery unit from the electronic device **103** based on the abnormality diagnosis results of the plurality of battery units **111**, **113**, and **115**. Herein, the isolation function may include electrical and/or mechanical isolation. Electrical isolation may involve controlling a switch connected to an electrical path between the abnormal battery unit and the electronic device **103** in a manner that electrically disconnects the abnormal battery unit from the electronic device **103**. Such a switch may be a relay positioned on the electrical path, whereby opening the relay results in electrical disconnection along the electrical path. Alternatively, the switch may be a branch from the electrical path, such as a short to ground or additional circuitry that effectively electrically disconnects the abnormal battery unit from the electronic device **103**. Mechanical isolation may also result in electrical disconnection along the electrical path, but may further involve a mechanical component to facilitate the electrical disconnection. For instance, a fuse may be used to disconnect the electrical path between the abnormal battery unit and the electronic device **103**. Alternatively, a switch may include one or more mechanical components that physically move or change position to disconnect the electrical path between the abnormal battery unit and the electronic device **103**.

[0081] FIG. **4** is a flowchart showing an operating method of the battery abnormality diagnosis apparatus **101** according to an embodiment of the present disclosure.

[0082] Referring to FIG. **4**, in operation **410**, the battery abnormality diagnosis apparatus **101** may obtain voltage-SOC profiles of the plurality of battery units **111**, **113**, and **115**. In an embodiment, the voltage-SOC profile may indicate a relationship between an SOC of a battery unit (e.g., the battery unit **111**) and a voltage.

[0083] In an embodiment, the battery abnormality diagnosis apparatus **101** may obtain the voltage-SOC profiles of the plurality of respective battery unit **111**, **113**, and **115** through the electronic device **103** connected through a wired and/or wireless network. In another embodiment, the battery abnormality diagnosis apparatus **101** may obtain voltages, currents, temperatures of the plurality of battery unit **111**, **113**, and **115**, or a combination thereof through the electronic device **103** connected through a wired and/or wireless network, and generate the voltage-SOC profiles based on the obtained voltages, currents, temperatures, or combination thereof.

[0084] In an embodiment, the battery abnormality diagnosis apparatus **101** may read the voltage, current, temperature, or a combination thereof, from each of the plurality of battery unit **111**, **113**, and **115**, and generate the voltage-SOC profiles based on the read voltage, current, temperature, or combination thereof.

[0085] In operation **420**, the battery abnormality diagnosis apparatus **101** may identify the ranks of the plurality of battery units **111**, **113**, and **115**. In an embodiment, the battery abnormality diagnosis apparatus **101** may identify the designated first number of ranks of each of the plurality of battery units **111**, **113**, and **115**, based on the voltage-SOC profiles. Herein, the designated first number may correspond to the number of SOC periods. Herein, the designated first number may be less than the number of SOC periods. Herein, the SOC periods may include periods for identifying an SOC during charging of the battery unit from 0% to 100%, and/or periods for identifying an SOC during discharging of the battery unit from 100% to 0%.

[0086] In an embodiment, the battery abnormality diagnosis apparatus **101** may identify representative voltage values of the SOC periods of the first number of each of the voltage-SOC profiles and identify the ranks based on the representative voltage values. Herein, the representative voltage value may be an average value of voltage values of each of the SOC periods of the first number.

[0087] In operation **430**, the battery abnormality diagnosis apparatus **101** may diagnose the abnormality of the plurality of battery units **111**, **113**, and **115**, based on the rank changes.

[0088] In an embodiment, the diagnosing unit **145** may diagnose, among the plurality of battery units **111**, **113**, and **115**, a battery unit having a rank changing by a reference value or greater, as an abnormal battery unit. Herein, the abnormal battery may include a degraded battery (or an over-degraded battery). The reference value may be an absolute distance, or a relative distance set based on the number of plurality of battery units. For example, a value corresponding to 200 (in the case of an absolute distance) or 90% of the number of battery units **111**, **113**, and **115** (or a rounded value, a rounded-down value, or a rounded-up value of the value corresponding to 90%) (in the case of relative distance) may be set to the reference value. For example, when the number of battery units **111**, **113**, and **115** is 238, the reference value may then be 200 for absolute distance, and 214 for relative distance. In another example, when the number of battery units **111**, **113**, and **115** is 196, the reference value may be less than 200, such as 160 for absolute distance, and 176 for relative distance.

[0089] In an embodiment, the diagnosing unit **145** may diagnose, among the plurality of battery units **111**, **113**, and **115**, a battery unit having a rank increasing by the reference value or greater or decreasing by the reference value or greater, as the abnormal battery unit. In an embodiment, the diagnosing unit **145** may diagnose, as the abnormal battery unit, at least one battery unit having the ranks increasing by the reference value or greater during charging or decreasing by the reference value or greater during discharging, among the plurality of battery units.

[0090] For example, when the reference value is 8, the diagnosing unit **145** has a rank increase of 8 between the rank of the SOC period R**1** and the rank of the SOC period R**4** and a rank decrease of 8 between the rank of the SOC period R**5** and the rank of the SOC period R**8**, such that the diagnosing unit **145** may diagnose the battery unit **113** as the abnormal battery unit.

[0091] In an embodiment, the battery abnormality diagnosis apparatus **101** may perform an abnormality processing function based on abnormality diagnosis results for the plurality of battery units **111**, **113**, and **115**. In an embodiment, the abnormality processing function may include a notification function or a short circuit function.

[0092] For example, in performing the notification function, the battery abnormality diagnosis apparatus **101** may transmit a notification containing the abnormality diagnosis results of the plurality of battery units **111**, **113**, and **115** to the user terminal **105** connected through a wired and/or wireless network.

[0093] In another embodiment, in performing the short circuit function, the battery abnormality diagnosis apparatus **101** may respond to the detected presence of a short circuit by performing an isolation function that isolates the abnormality battery unit from the electronic device **103** based on the abnormality diagnosis results of the plurality of battery units **111**, **113**, and **115**. Herein, the isolation function may include electrical and/or mechanical isolation. Electrical isolation may involve controlling a switch connected to an electrical path between the abnormal battery unit and the electronic device **103** in a manner that electrically disconnects the abnormal battery unit from the electronic device **103**. Such a switch may be a relay positioned on the electrical path, whereby opening the relay results in electrical disconnection along the electrical path. Alternatively, the switch may be a branch from the electrical path, such as a short to ground or additional circuitry that effectively electrically disconnects the abnormal battery unit from the electronic device **103**. Mechanical isolation may also result in electrical disconnection along the electrical path, but may further involve a mechanical component to facilitate the electrical disconnection. For instance, a fuse may be used to disconnect the electrical path between the abnormal battery unit and the electronic device **103**. Alternatively, a switch may include one or more mechanical components that physically move or change position to disconnect the electrical path between the abnormal battery unit and the electronic device **103**.

[0094] FIG. **5** is a flowchart showing an operating method of the battery abnormality diagnosis apparatus **101** according to an embodiment of the present disclosure. Operations of FIG. **5** may be performed for each of the battery units **111**, **113**, and **115**. Operations of FIG. **5** may be included in operation **430** of FIG. **4**.

[0095] Referring to FIG. **5**, in operation **510**, the battery abnormality diagnosis apparatus **101** may identify a rank change of a battery unit.

[0096] In operation **520**, the battery abnormality diagnosis apparatus **101** may determine whether the rank increases by the reference value or greater during discharging. The reference value may be set based on the number of plurality of battery units. For example, a value corresponding to 90% of the number of battery units **111**, **113**, and **115** (or a rounded value, a rounded-down value, or a rounded-up value of the value corresponding to 90%) may be set to the reference value. For example, when the number of battery units **111**, **113**, and **115** is 238, the reference value may be 214. In another example, when the number of battery units **111**, **113**, and **115** is 196, the reference value may be 176.

[0097] In an embodiment, the battery abnormality diagnosis apparatus **101** may determine whether there is a period in which the rank increases by the reference value or greater during charging.

[0098] As a determination result in operation **520**, when the rank increases by the reference value or greater during charging (Yes), the battery abnormality diagnosis apparatus **101** may perform operation **530**. As a determination result in operation **520**, when the rank does not increase by the reference value or greater during charging (No), the battery abnormality diagnosis apparatus **101** may perform operation **550**.

[0099] In operation **530**, the battery abnormality diagnosis apparatus **101** may determine whether the rank decreases by the reference value or greater during discharging. Herein, the reference value may be identical to the reference value in operation **520**.

[0100] In an embodiment, the battery abnormality diagnosis apparatus **101** may determine whether the rank decreases by the reference value or greater during discharging.

[0101] As a determination result in operation **530**, when the rank decreases by the reference value or greater during discharging (Yes), the battery abnormality diagnosis apparatus **101** may perform operation **540**. As a determination result in operation **530**, when the rank does not decrease by the reference value or greater during discharging (No), the battery abnormality diagnosis apparatus **101** may perform operation **550**.

[0102] In operation **540**, the battery abnormality diagnosis apparatus **101** may diagnose the battery unit as an abnormal battery.

[0103] In operation **550**, the battery abnormality diagnosis apparatus **101** may diagnose the battery unit as a normal battery.

[0104] According to an embodiment, operation **520** and **530** may be performed at the same time. According to an embodiment, operation **520** may performed after operation **530**.

Claims

1. A battery abnormality diagnosis apparatus comprising: a processor; and memory having programmed thereon instructions, wherein the instructions are configured to cause the processor to: for each battery unit of a plurality of battery units obtain a respective voltage-state-of-charge (SOC) profile of a battery unit, wherein the respective voltage-SOC profile includes state-of-charge information for each of a plurality of charging cycles of the battery unit and a plurality of discharging cycles of the battery unit; for each battery unit of the plurality of battery units, identify a ranking of the battery unit among the plurality of battery units for each of the charging cycles and each of the discharging cycles included in the respective voltage-SOC profile, based on the state-of-charge information included in the respective voltage-SOC profile; and diagnose abnormality of the plurality of battery units, based on changes of the identified rankings.
2. The battery abnormality diagnosis apparatus of claim 1, wherein each SOC voltage profile includes a plurality of SOC periods, and wherein the instructions are configured to cause the processor to: for each battery unit of the plurality of battery units, for two or more SOC periods of the voltage SOC profile, identify a representative voltage value of the SOC period, wherein, for each SOC period of the two or more SOC periods, the ranking of the battery unit at the SOC period is based on the respective representative voltage value of the battery unit for the SOC period.
3. The battery abnormality diagnosis apparatus of claim 2, wherein the instructions are configured to cause the processor to, for each battery unit of the plurality of battery units, for each SOC period of the two or more SOC periods, set the representative voltage value of the SOC period equal to an average value of voltage values of the battery unit for the SOC period.
4. The battery abnormality diagnosis apparatus of claim 1, wherein the instructions are configured to cause the processor to diagnose at least one battery unit of the plurality of battery units as abnormal based on fulfillment of a first condition during charging or a second condition during discharging, wherein the second condition is different than the first condition, and wherein each of the first condition and the second condition relates to the ranking of the at least one battery unit changing by a reference value or greater over time.
5. The battery abnormality diagnosis apparatus of claim 4, wherein the reference value is a function of a total number of the plurality of battery units.
6. The battery abnormality diagnosis apparatus of claim 4, wherein the first condition is the ranking of the at least one battery unit increasing by the reference value or greater during charging, and wherein the second condition is the ranking of the at least one battery unit decreasing by the reference value or greater during discharging.
7. The battery abnormality diagnosis apparatus of claim 1, wherein the instructions are configured to cause the processor to obtain the voltage-SOC profiles of the plurality of battery units through an external electronic device connected to the battery abnormality diagnosis apparatus through a wired and/or wireless network.
8. The battery abnormality diagnosis apparatus of claim 1, wherein the instructions are configured to cause the processor to: for each battery unit of the plurality of battery units: read a voltage, a current, a temperature, or a combination thereof from the battery unit; and generate the respective voltage-SOC profile of the battery unit based on the read voltage, current, temperature, or combination thereof.
9. The battery abnormality diagnosis apparatus of claim 1, wherein the plurality of battery units comprise one of a battery cell, a battery module, a battery pack, or a battery rack.
10. The battery abnormality diagnosis apparatus of claim 1, wherein the instructions are configured to cause the processor to perform an abnormality processing function based on an abnormality diagnosis result of the plurality of battery units, wherein the abnormality processing function comprises a notification function or an isolation function.

11. An operating method of a battery abnormality diagnosis apparatus, the operating method comprising: for each battery unit of a plurality of battery units, obtaining a voltage-state-of-charge (SOC) profile of a battery unit; for each battery unit of the plurality of battery units, identifying a ranking of the battery unit among the plurality of battery units based on the respective voltage-SOC profile; and diagnosing abnormality of the plurality of battery units, based on changes of the identified rankings over time.

12. The operating method of claim 11, wherein each SOC voltage profile includes a plurality of SOC periods, wherein the method further comprises: for each battery unit of the plurality of battery units, for two or more SOC periods of the voltage SOC profile, identifying a representative voltage value of the SOC period, wherein identifying the ranking of the battery unit comprises, for each SOC period of the two or more SOC periods, identifying the ranking of the battery unit at the SOC period based on the respective representative voltage value of the battery unit for the SOC period.

13. The operating method of claim 12, wherein the method further comprises, for each battery unit of the plurality of battery units, for each SOC period of the two or more SOC periods, setting the representative voltage value of the SOC period equal to an average value of voltage values of the battery unit for the SOC period.

14. The operating method of claim 11, wherein diagnosing abnormality of the plurality of battery units comprises diagnosing at least one battery unit of the plurality of battery units as abnormal based on fulfillment of a first condition during charging or a second condition during discharging, wherein the second condition is different than the first condition, and wherein each of the first condition and the second condition relates to the ranking of the at least one battery changing by a reference value or greater over time.

15. The operating method of claim 14, wherein the reference value is a function of a total number of the plurality of battery units.

16. The operating method of claim 14, wherein the first condition is the ranking of the at least one battery unit increasing by the reference value or greater during charging, and wherein the second condition is the ranking of the at least one battery unit decreasing by the reference value or greater during discharging.

17. The operating method of claim 11, wherein obtaining the voltage SOC profile is performed through an external electronic device connected to the battery abnormality diagnosis apparatus through a wired and/or wireless network.

18. The operating method of claim 11, wherein obtaining the voltage SOC profile comprises: for each battery unit of the plurality of battery units: reading a voltage, a current, a temperature, or a combination thereof from the battery unit; and generating the respective voltage-SOC profile of the battery unit based on the read voltage, current, temperature, or combination thereof.

19. The operating method of claim 11, wherein the plurality of battery units comprise one of a battery cell, a battery module, a battery pack, or a battery rack.

20. The operating method of claim 11, further comprising performing an abnormality processing function based on an abnormality diagnosis result of the plurality of battery units, wherein the abnormality processing function comprises a notification function or an isolation function.