

# US Patent & Trademark Office

## Patent Public Search | Text View

United States Patent Application Publication

20250258243

Kind Code

A1

Publication Date

August 14, 2025

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### APPARATUS AND METHOD FOR DIAGNOSING BATTERY ASSEMBLY

#### Abstract

A method for diagnosing a battery assembly according to one aspect of the present disclosure diagnoses a battery assembly including a battery bank provided by connecting a plurality of battery cells in parallel with each other, and the method includes generating a second differential profile representing a relationship between a second differential capacity, which is obtained by taking a second derivative of a capacity of the battery bank with respect to a voltage of the battery bank, and the voltage of the battery bank; and detecting a target peak located in a predetermined voltage section among a plurality of peaks of the second differential profile and diagnosing a state of the battery bank based on a second differential capacity value of the target peak.

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**Family ID:** 94389468

**Appl. No.:** 19/047527

**Filed:** February 06, 2025

#### Foreign Application Priority Data

KR 10-2024-0019807

Feb. 08, 2024

#### Publication Classification

**Int. Cl.:** G01R31/392 (20190101); G01R31/3842 (20190101); G01R31/396 (20190101); H01M10/42 (20060101); H01M10/44 (20060101); H01M10/48 (20060101)

**U.S. Cl.:**

## Background/Summary

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and claims priority from Korean Patent Application No. 10-2024-0019807, filed on Feb. 8, 2024, with the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

### TECHNICAL FIELD

[0002] The present disclosure relates to an apparatus and method for diagnosing a battery assembly, and more particularly, to an apparatus and method for non-destructively diagnosing a state of a battery assembly capable of charging and discharging.

### BACKGROUND

[0003] Recently, the demand for portable electronic products such as notebook computers, digital cameras and portable telephones has increased sharply, and electric vehicles, energy storage systems, robots, satellites and the like have been developed in earnest. Accordingly, high-performance batteries allowing charging and discharging and having a high energy density are being actively studied.

[0004] Types of rechargeable batteries include lithium batteries that use lithium ions, such as lithium-ion batteries or lithium-ion polymer batteries, and nickel cadmium batteries, nickel hydrogen batteries, and nickel zinc batteries. Among these, lithium batteries have the advantages of having a relatively long lifespan, a very low self-discharge rate, and high energy density because they have almost no memory effect compared to batteries that use nickel, and thus their application range is gradually expanding.

[0005] The positive electrode and negative electrode of these batteries gradually deteriorate as the charge and discharge cycles are repeated, and they no longer maintain the electrical capacity they had at the time of manufacture but are deteriorated. Therefore, in order to accurately predict the usable time, remaining life, and replacement time of the battery, an accurate diagnosis of the battery state is required.

[0006] However, in diagnosing the battery assembly (e.g., battery module or battery pack) that includes a plurality of battery cells corresponding to the basic units of charge and discharge, the existing technologies perform diagnosis based on the SOH (State of Health) of the corresponding battery assembly. Therefore, when the battery assembly includes a plurality of battery banks that are provided by connecting a plurality of battery cells in parallel with each other, the existing technologies have a problem in that they cannot diagnose the state of the corresponding battery assembly for each battery bank, and cannot diagnose whether the battery cells of each battery bank are deteriorated unevenly.

### SUMMARY

[0007] Aspects of the present disclosure are designed to at least partly address, and even solve, the problems of the related art, and therefore the present disclosure is directed to providing an apparatus and method for diagnosing a battery assembly, which may diagnose the state of a battery assembly including a plurality of battery banks, which are formed by connecting a plurality of battery cells in parallel, for each battery bank, and may diagnose whether the battery cells of each battery bank have deteriorated unevenly.

[0008] Another technical challenge that aspects of the present disclosure seek to address is to provide an apparatus and method for diagnosing a battery that may extend the life of a battery

assembly and improve safety.

[0009] A method for diagnosing a battery assembly according to one aspect of the present disclosure diagnoses a battery assembly including a battery bank comprising a plurality of battery cells connected in parallel with each other, and the method comprises generating a second differential profile representing a relationship between a second differential capacity, which is obtained by taking a second derivative of a capacity of the battery bank with respect to a voltage of the battery bank, and the voltage of the battery bank; and detecting a target peak located in a predetermined voltage section among a plurality of peaks of the second differential profile and diagnosing a state of the battery bank based on a second differential capacity value of the target peak.

[0010] In an embodiment, the generating the second differential profile may include a step of repeatedly measuring a voltage value and a current value of the battery bank using at least one electrical sensor while the battery bank is being charged or discharged; and generating the second differential profile using the voltage values and the current values measured while the battery bank is being charged or discharged.

[0011] In an embodiment, generating the second differential profile may include generating a profile representing the relationship between the voltage and the capacity of the battery bank; generating a first differential profile by differentiating the profile with respect to the voltage of the battery bank; and generating the second differential profile by differentiating the first differential profile with respect to the voltage of the battery bank.

[0012] In an embodiment, diagnosing the state of the battery bank may include comparing the second differential capacity value of the target peak with a predetermined threshold value, and diagnosing the state of the battery bank as an abnormal state when the second differential capacity value is less than a threshold value.

[0013] In an embodiment, diagnosing the state of the battery bank may include diagnosing the state of the battery bank as an abnormal state in which the plurality of battery cells are unevenly deteriorated, when the second differential capacity value of the target peak is less than a predetermined threshold value and the number of peaks located in the predetermined voltage section exceeds a predetermined reference number.

[0014] In an embodiment, the battery assembly may include a plurality of battery banks, the method may further comprise generating a plurality of second differential profiles respectively corresponding to the plurality of battery banks included in the battery assembly, and diagnosing a state of each of the plurality of battery banks as a normal state or an abnormal state based on the plurality of second differential profiles.

[0015] In an embodiment, diagnosing that state of the battery bank may include diagnosing the state of the battery bank as an abnormal state when the second differential capacity value of the target peak is less than a predetermined threshold value, and the method for diagnosing the battery may further comprise controlling a charger that charges the battery bank to reduce a voltage at an end of charging of the battery bank or reduce a current rate of a current that charges the battery bank, when the state of the battery bank is diagnosed as an abnormal state.

[0016] An apparatus for diagnosing a battery assembly according to another aspect of the present disclosure diagnoses a battery assembly including a battery bank provided by connecting a plurality of battery cells in parallel with each other, and the apparatus comprises a second differential profile generating unit configured to generate a second differential profile representing a relationship between a second differential capacity, which is obtained by taking a second derivative of a capacity of the battery bank with respect to a voltage of the battery bank, and the voltage of the battery bank; and a diagnosing unit configured to detect a target peak located in a predetermined voltage section among a plurality of peaks of the second differential profile and diagnose a state of the battery bank based on a second differential capacity value of the target peak.

[0017] In an embodiment, the diagnosing unit may be configured to compare the second

differential capacity value of the target peak with a predetermined threshold value, and diagnose the state of the battery bank as an abnormal state when the second differential capacity value is less than a threshold value.

[0018] In an embodiment, the diagnosing unit may be configured to diagnose the state of the battery bank as an abnormal state in which the plurality of battery cells are unevenly deteriorated, when the second differential capacity value of the target peak is less than a predetermined threshold value and the number of peaks located in the predetermined voltage section exceeds a predetermined reference number.

[0019] In an embodiment, the battery assembly may include a plurality of battery banks, the second differential profile generating unit may be configured to generate a plurality of second differential profiles respectively corresponding to the plurality of battery banks included in the battery assembly, and the diagnosing unit may be configured to diagnose a state of each of the plurality of battery banks as a normal state or an abnormal state based on the plurality of second differential profiles.

[0020] In an embodiment, the diagnosing unit may be configured to diagnose the state of the battery bank as an abnormal state when the second differential capacity value of the target peak is less than a predetermined threshold value, and the apparatus for diagnosing a battery may further comprise a battery management unit configured to control a charger that charges the battery bank to reduce a voltage at an end of charging of the battery bank or reduce a current rate of a current that charges the battery bank, when the state of the battery bank is diagnosed as an abnormal state.

[0021] A battery pack according to still another aspect of the present disclosure may comprise the apparatus for diagnosing a battery as described above.

[0022] A vehicle according to still another aspect of the present disclosure may comprise the apparatus for diagnosing a battery as described above.

[0023] Embodiments of the present disclosure diagnose the state of a battery bank by using the second differential profile, which represents the relationship between the second differential capacity, which is obtained by taking a second derivative of the battery bank included in the battery assembly with respect to the voltage of the battery bank, and the voltage of the battery bank, thereby enabling the diagnosis of the state of the battery assembly including a plurality of battery banks for each battery bank, and improving the accuracy and reliability of the diagnosis result.

[0024] In addition, embodiments of the present disclosure may accurately diagnose whether the battery cells are deteriorated unevenly in a battery bank that is formed by connecting the battery cells in parallel by diagnosing the state of the battery bank based on the second differential capacity value of a target peak located in a predetermined voltage section among a plurality of peaks of the second differential profile.

[0025] In addition, embodiments of the present disclosure may perform management of a battery assembly including a plurality of battery banks for each battery bank by controlling the charge and/or discharge conditions of the corresponding battery bank according to the diagnosis result of the battery bank, thereby extending the life of the entire battery assembly and improving safety.

[0026] Furthermore, a person having ordinary skill in the art to which the present disclosure belongs will be able to clearly understand from the following description that various embodiments according to the present disclosure can solve various technical problems not mentioned above.

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## Description

### DESCRIPTION OF DRAWINGS

[0027] FIG. 1 is a block diagram showing an apparatus for diagnosing a battery assembly according to an embodiment of the present disclosure.

[0028] FIG. 2 is a drawing showing an example of a battery assembly to be diagnosed according to

the present disclosure.

[0029] FIG. 3 is a drawing showing an example of a profile showing the relationship between the capacity and voltage of a battery bank.

[0030] FIG. 4 is a drawing showing an example of a first differential profile of a normal battery bank.

[0031] FIG. 5 is a drawing showing an example of a second differential profile of a normal battery bank.

[0032] FIG. 6 is a drawing showing an example of a first differential profile of an abnormal battery bank.

[0033] FIG. 7 is a drawing showing an example of second differential profile of an abnormal battery bank.

[0034] FIG. 8 is a graph showing an example of the change in the second differential capacity value of a first target peak according to the uneven deterioration of the battery bank.

[0035] FIG. 9 is a graph showing an example of the change in the second differential capacity value of a second target peak according to the uneven deterioration of the battery bank.

[0036] FIG. 10 is a flow chart showing a method for diagnosing a battery assembly according to an embodiment of the present disclosure.

[0037] FIG. 11 is a drawing showing a battery pack according to an embodiment of the present disclosure.

[0038] FIG. 12 is a drawing showing a vehicle according to an embodiment of the present disclosure.

#### DETAILED DESCRIPTION

[0039] Hereinafter, in order to clarify one or more solutions corresponding to the technical challenge of the present disclosure, embodiments according to the present disclosure will be described in detail with reference to the attached drawings. However, when explaining the present disclosure, if a description of a related publicly known technology obscures the gist of the present disclosure, the description thereof may be omitted. In addition, the terms used in this specification are terms defined in consideration of the functions in the present disclosure, and these may vary depending on the intention or custom of the designer, manufacturer, etc. Therefore, the definitions of the terms described below should be made based on the contents throughout this specification.

[0040] FIG. 1 is a block diagram showing an apparatus **100** for diagnosing a battery assembly according to an embodiment of the present disclosure.

[0041] As illustrated in FIG. 1, the apparatus **100** for diagnosing a battery assembly according to an embodiment of the present disclosure includes a control unit **110**. The control unit **110** is configured to non-destructively diagnose a battery assembly including one or more battery banks formed by connecting a plurality of rechargeable battery cells in parallel.

[0042] To this end, the control unit **110** may include one or more general-purpose processors or ASICs (application-specific integrated circuits) for executing the battery diagnosis logic, and may optionally further include hardware such as registers and memories according to an embodiment. The control unit **110** may be configured with a combination of hardware such as a processor and software such as a computer program. That is, the battery diagnosis logic of the control unit **110** may be configured as a computer program and stored in the memory of the control unit **110** or a storage unit **140** described below, and the stored computer program may be configured to be executed through the hardware of the control unit **110**.

[0043] Meanwhile, the control unit **110** is a detailed component for diagnosing the battery assembly and includes a second differential profile generating unit **112** and a diagnosing unit **114**.

[0044] The second differential profile generating unit **112** is configured to generate a second differential profile representing the relationship between the second differential capacity, which is obtained by taking a second derivative of the capacity of a battery bank included in a battery assembly with respect to the voltage of the battery bank, and the voltage of the battery bank.

[0045] In an embodiment, the second differential profile generating unit **112** may include a measurement module **112a**, a first generation module **112b**, and a second generation module **112c**.

[0046] In this case, the measurement module **112a** may be configured to repeatedly measure the voltage value and current value of the battery bank using at least one electrical sensor while the battery bank is being charged or discharged.

[0047] The first generation module **112b** and the second generation module **112c** may generate the second differential profile using the voltage values and current values measured by the measurement module **112a** while the battery bank is being charged or discharged.

[0048] For example, the first generation module **112b** may be configured to generate a profile representing the relationship between the voltage and capacity of the battery bank using voltage values and current values measured while the battery bank is being charged or discharged.

[0049] The second generation module **112c** may be configured to generate a first differential profile by differentiating the generated profile with respect to the voltage of the battery bank, and to generate the second differential profile by differentiating the first differential profile with respect to the voltage of the battery bank.

[0050] The diagnosing unit **114** is configured to detect a target peak located in a predetermined voltage section among a plurality of peaks of the second differential profile, and diagnose the state of the battery bank based on the second differential capacity value of the target peak.

[0051] The voltage section where the target peak is located may be experimentally determined. That is, the voltage section where the peak where splitting occurs due to uneven degradation of the battery bank among the peaks of the second differential profile is located may be experimentally confirmed, and the confirmed voltage section may be determined as the voltage section where the target peak is located.

[0052] In an embodiment, the diagnosing unit **114** may be configured to compare the second differential capacity value of the target peak with a predetermined threshold value, and to diagnose the state of the battery bank as an abnormal state if the second differential capacity value is less than the threshold value. In this case, the abnormal state may mean a state in which a plurality of battery cells forming the battery bank are unevenly deteriorated.

[0053] The threshold value may be the minimum value among the second differential capacity values that the target peak of the normal battery bank may have, or a value determined during the design of the battery assembly.

[0054] In another embodiment, the diagnosing unit **114** may be configured to diagnose the state of the battery bank as an abnormal state if the second differential capacity value of the target peak is less than a predetermined threshold value and the number of peaks located in the predetermined voltage section exceeds a predetermined reference number. In this case, the abnormal state may mean a state in which a plurality of battery cells forming the battery bank are unevenly deteriorated.

[0055] In another embodiment, the diagnosing unit **114** may be configured to determine the state of the battery bank based on a plurality of target peaks.

[0056] In this case, the diagnosing unit **114** may be configured to detect a first target peak located in a first voltage section and a second target peak located in a second voltage section among predetermined voltage sections.

[0057] And, the diagnosing unit **114** may be configured to determine the state of the battery bank as an abnormal state if the second differential capacity value of the first target peak is less than a predetermined first threshold value and the second differential capacity value of the second target peak is less than a predetermined second threshold value. In this case, the abnormal state may mean a state in which a plurality of battery cells included in the battery bank are unevenly deteriorated.

[0058] In an embodiment, when the battery assembly to be diagnosed includes a plurality of battery banks, the second differential profile generating unit **112** may be configured to generate a plurality of second differential profiles respectively corresponding to the plurality of battery banks.

[0059] In this case, the diagnosing unit **114** may be configured to diagnose the state of each of the plurality of battery banks as a normal state or an abnormal state based on the plurality of second differential profiles.

[0060] In an embodiment, the control unit **110** may further include a diagnosis result informing unit **116**. In this case, the diagnosis result informing unit **116** may be configured to output a visual, auditory or audio-visual notification signal corresponding to the diagnosis result of the battery bank using a predetermined output device.

[0061] In an embodiment, the control unit **110** may further include a battery management unit **118**. In this case, the battery management unit **118** may be configured to control a charging condition and/or a discharging condition of the battery bank according to the diagnosis result for the battery bank.

[0062] For example, when an abnormal battery bank diagnosed as an abnormal state is detected by the diagnosing unit **114** among the plurality of battery banks included in the battery assembly, the battery management unit **118** may be configured to control a charger that charges the abnormal battery bank to reduce a voltage at the end of charging of the abnormal battery bank or reduce a current rate of a current that charges the abnormal battery bank.

[0063] Meanwhile, the battery management unit **118** may be configured to control the cooling device **18** described later to lower the temperature of an abnormal battery bank.

[0064] The second differential profile generating unit **112**, the diagnosing unit **114**, the diagnosis result informing unit **116**, and the battery management unit **118** of the above-described control unit **110** may be implemented as a combination of a processor and a program executed by the processor. In this case, the control unit **110** may be implemented as a single processor, or may be implemented as two or more processors that are interconnected.

[0065] In an embodiment, the apparatus **100** for diagnosing a battery may further include a communication unit **120**. The communication unit **120** may be configured to receive data transmitted from a remotely located server or communication terminal via a wired and/or wireless communication network and transmit the data to the control unit **110**, or transmit control signals, diagnostic data, etc. processed by the control unit **110** to the remotely located server or communication terminal. To this end, the communication unit **120** may include a communication modem that performs wired and/or wireless communication.

[0066] In an embodiment, the apparatus **100** for diagnosing a battery may further include an input unit **130**. The input unit **130** may be configured to receive commands or data from a user or an administrator. For this purpose, the input unit **130** may include an input device such as a keyboard, operating buttons, or a touch panel.

[0067] In an embodiment, the apparatus **100** for diagnosing a battery may further include a storage unit **140**. The storage unit **140** may be configured to store and manage data required for the operation of the apparatus **100** for diagnosing a battery. To this end, the storage unit **140** may include one or two or more of a ROM, a RAM, an EEPROM, a register, a flash memory, a CD-ROM, a magnetic tape, a hard disk, a floppy disk, and an optical data recording device.

[0068] In an embodiment, the apparatus **100** for diagnosing a battery may further include an output unit **150**. The output unit **150** may be configured to visually, audibly or audiovisually output a notification signal of the diagnosis result informing unit **116**. For this purpose, the output unit **150** may include a visual output device such as a light-emitting diode, a monitor, a display panel or a touch screen. In addition, the output unit **150** may further include a sound generating device such as a speaker.

[0069] In an embodiment, the apparatus **100** for diagnosing a battery may be configured to be interlocked with a measurement device **12** for measuring voltage and/or current of a battery assembly to be diagnosed, a communication device **14** for communicating with another device, a charging/discharging device **16** for charging and discharging battery banks included in the battery assembly, a cooling device **18** for cooling the battery banks included in the battery assembly, etc.

[0070] In another embodiment, the apparatus **100** for diagnosing a battery according to the present disclosure may include one or more of the measurement device **12**, the communication device **14**, the charging/discharging device **16**, and the cooling device **18** described above.

[0071] FIG. **2** is a drawing showing an example of a battery assembly BA to be diagnosed according to the present disclosure.

[0072] As illustrated in FIG. **2**, the battery assembly BA, which is the diagnostic target of the present disclosure, may include a plurality of battery banks BB1 to BBn. In this case, the plurality of battery banks BB1 to BBn may be connected in series with each other, or may be connected in a manner that mixes series and parallel connections. In addition, each battery bank may include a plurality of battery cells BC that are connected in parallel with each other.

[0073] Such a battery assembly BA may be implemented as a battery module or a battery pack including battery banks and a case that accommodates the battery banks.

[0074] In this way, since the plurality of battery cells BC included in each battery bank are connected in parallel with each other, it is difficult to measure the voltage of each battery cell. Therefore, the existing technology that estimates the SOC or SOH of the battery assembly by using the voltage, current, temperature, etc. of the entire battery assembly as parameters may not be able to diagnose the state of the battery assembly for each battery bank, and may not be able to determine whether the battery cells of the above-mentioned battery bank are deteriorated unevenly.

[0075] On the other hand, the apparatus **100** for diagnosing the battery assembly according to aspects of the present disclosure measures the voltage (V1) and current (I1) of the battery bank BB1 while the battery bank BB1 is being charged or discharged, generates a profile representing the relationship between the voltage and capacity of the battery bank BB1, and uses a second differential profile obtained by taking a second derivative of this profile to diagnose the state of the battery bank, thereby making it possible to diagnose the state of the battery assembly for each battery bank and accurately determine whether the battery cells of the battery bank have deteriorated unevenly.

[0076] FIG. **3** is a drawing showing an example of a profile showing the relationship between the capacity and voltage of a battery bank.

[0077] As illustrated in FIG. **3**, the second differential profile generating unit **112** may generate a profile BP representing a relationship between the capacity and voltage of the battery bank BB1 by measuring electrical values (V1, I1) of the battery bank BB1 while the battery bank BB1 of FIG. **2** is being charged or discharged. In this case, the capacity of the battery bank may be expressed as a SOC (State of Charge) value using a unit of percentage (%). For reference, the electric capacity possessed by the battery bank BB1 may be calculated by applying a current integration method to the current (I1) that charges the battery bank BB1.

[0078] Meanwhile, the second differential profile generating unit **112** may find the positive electrode profile PP and the negative electrode profile NP which generate a curve similar to the profile BP by mutual combination, and provide the start point (pi) and the end point (pf) of the positive electrode profile PP, the shrinkage ratio (ps) of the positive electrode profile PP compared with the reference positive electrode profile, the start point (ni) and the end point (nf) of the negative electrode profile NP, the shrinkage ratio (ns) of the negative electrode profile NP compared with the reference negative electrode profile, etc., to the diagnosing unit **114**. The diagnosing unit **114** may use the start point (pi), the end point (pf) and the shrinkage ratio (ps) of the positive electrode profile PP, and the start point (ni), the end point (nf) and the shrinkage ratio (ns) of the negative electrode profile NP as diagnostic factors indicating the state of the battery bank BB1.

[0079] In addition, the second differential profile generating unit **112** may generate the second differential profile by taking a second derivative of the profile BP with respect to the voltage of the battery.

[0080] FIG. **4** is a drawing showing a first differential profile BP'1 of a normal battery bank.



[0081] As illustrated in FIG. 4, the second differential profile generating unit **112** may generate a first differential profile BP'1 by differentiating the profile representing the relationship between the voltage and capacity of the battery bank charged at a current rate of 0.33 [C] with respect to the voltage of the battery bank.

[0082] And, the second differential profile generating unit **112** may generate the second differential profile by differentiating the first differential profile BP'1 again with respect to the voltage of the battery bank.

[0083] FIG. 5 is a drawing showing a second differential profile BP''1 of a normal battery bank.

[0084] As illustrated in FIG. 5, the second differential profile generating unit **112** may generate a second differential profile BP''1 representing the relationship between the second differential capacity ( $d.\text{sup.}2Q/dV.\text{sup.}2$ ), which is the second derivative of the capacity of the battery bank with respect to the voltage of the battery bank, and the voltage of the battery bank, for each battery bank at a predetermined diagnostic cycle.

[0085] Then, the diagnosing unit **114** may diagnose the state of the battery bank based on the second differential capacity value of the target peak (Pa1) located in the predetermined voltage section (S1) among the plurality of peaks of the second differential profile BP''1. For example, the voltage section (S1) may be a section from 3.45 [V] to 3.55 [V].

[0086] For example, if the second differential capacity value of the target peak (Pa1) is less than a predetermined threshold value, the diagnosing unit **114** may diagnose the state of the battery bank as an abnormal state. In this case, the abnormal state may mean a state in which the plurality of battery cells forming the battery bank are unevenly deteriorated.

[0087] The threshold value may be the minimum value among the second differential capacity values that the target peak of the normal battery bank can have, or a value determined during the design of the battery assembly.

[0088] In an embodiment, the diagnosing unit **114** may be configured to determine the state of the battery bank based on a plurality of target peaks.

[0089] In this case, the diagnosing unit **114** may detect a first target peak (Pa1) located in a first voltage section (S1) among predetermined voltage sections, and a second target peak (Pb1) located in a second voltage section (S2). For example, the first voltage section (S1) may be a section from 3.45 [V] to 3.55 [V], and the second voltage section (S2) may be a section from 3.60 [V] to 3.70 [V].

[0090] Next, the diagnosing unit **114** may determine the state of the battery bank as an abnormal state if the second differential capacity value of the first target peak (Pa1) is less than a predetermined first threshold value and the second differential capacity value of the second target peak (Pb1) is less than a predetermined second threshold value. The abnormal state may mean a state in which the plurality of battery cells of the battery bank are unevenly deteriorated.

[0091] FIG. 6 is a drawing showing a first differential profile BP'2 of an abnormal battery bank.

[0092] As illustrated in FIG. 6, the first differential profile BP'2 of the abnormal battery bank in which battery cells are unevenly deteriorated shows a different pattern from the first differential profile BP'1 of the normal battery bank illustrated in FIG. 4. That is, the first differential profile BP'2 of the abnormal battery bank has a reduced slope change compared to the first differential profile BP'1 of the normal battery bank.

[0093] FIG. 7 is a drawing showing a second differential profile BP''2 of an abnormal battery bank.

[0094] As illustrated in FIG. 7, the second differential capacity value of the first target peak (Pa2) in the second differential profile BP''2 of an abnormal battery bank in which the battery cells are unevenly deteriorated is reduced compared to the second differential capacity value of the first target peak (Pa1) in the second differential profile BP''1 of a normal battery bank.

[0095] Similarly, the second differential capacity value of the second target peak (Pb2) appearing in the second differential profile BP''2 of the abnormal battery bank is reduced compared to the second differential capacity value of the second target peak (Pb1) appearing in the second

differential profile BP''1 of the normal battery bank.

[0096] Therefore, the diagnosing unit **114** may determine the state of the battery bank as an abnormal state if the second differential capacity value of the first target peak (Pa2) is less than a predetermined first threshold value.

[0097] In another embodiment, the diagnosing unit **114** may determine the state of the battery bank as an abnormal state if the second differential capacity value of the first target peak (Pa2) is less than the first threshold value and the second differential capacity value of the second target peak (Pb2) is less than a predetermined second threshold value. In this case, the abnormal state may mean a state in which the plurality of battery cells of the battery bank are unevenly deteriorated.

[0098] Meanwhile, additional peaks (SPa, SPb) may occur around the first target peak (Pa2) and the second target peak (Pb2) of the second differential profile BP''2 of the abnormal battery bank due to the peak splitting phenomenon caused by uneven deterioration of the battery bank.

[0099] Therefore, the diagnosing unit **114** may diagnose the state of the battery bank as an abnormal state if at least one of the second differential capacity value of the first target peak (Pa2) and the second differential capacity value of the second target peak (Pb2) is less than a predetermined threshold value and the number of peaks located in the predetermined voltage section (S1, S2) exceeds a predetermined reference number. In this case, the abnormal state may mean a state in which the plurality of battery cells of the battery bank are unevenly deteriorated.

[0100] FIG. **8** is a graph showing the change in the second differential capacity value of a first target peak (Pa2) according to the uneven deterioration of the battery bank.

[0101] As shown in FIG. **8**, when the battery cells of the battery bank are deteriorated unevenly, the second differential capacity value of the first target peak (Pa2) located in the first voltage section (S1) of the second differential profile BP''2 gradually decreases over time.

[0102] In addition, when the time point (t1) at which the second differential capacity value of the first target peak (Pa2) becomes smaller than the first threshold value (Qr''1) is reached, a peak splitting phenomenon occurs in the first target peak (Pa2).

[0103] FIG. **9** is a graph showing the change in the second differential capacity value of a second target peak (Pb2) according to the uneven deterioration of the battery bank.

[0104] As shown in FIG. **9**, when the battery cells of the battery bank are deteriorated unevenly, the second differential capacity value of the second target peak (Pb2) located in the second voltage section (S2) of the second differential profile BP''2 gradually decreases over time.

[0105] In addition, when the time point (t2) at which the second differential capacity value of the second target peak (Pb2) becomes smaller than the second threshold value (Qr''2) occurs, a peak splitting phenomenon occurs in the second target peak (Pb2).

[0106] FIG. **10** is a flow chart showing a method for diagnosing a battery assembly according to an embodiment of the present disclosure.

[0107] As illustrated in FIG. **10**, the method for diagnosing a battery assembly according to the present disclosure is a method for non-destructively diagnosing a battery assembly including a battery bank provided by connecting a plurality of battery cells in parallel with each other, and may be performed by a processor.

[0108] First, the processor generates a second differential profile representing the relationship between a second differential capacity, which is obtained by taking a second derivative of the capacity of the battery bank included in the battery assembly with respect to the voltage of the battery bank, and the voltage of the battery bank (S10).

[0109] In this case, the processor may repeatedly measure the voltage value and current value of the battery bank using at least one electrical sensor while the battery bank is being charged or discharged.

[0110] Then, the processor may generate the second differential profile using the voltage values and current values measured while the battery bank is being charged or discharged.

[0111] For example, the processor may generate a profile representing the relationship between the

voltage and capacity of the battery bank using voltage values and current values measured while the battery bank is being charged or discharged.

[0112] Next, the processor may generate a first differential profile by differentiating the generated profile with respect to the voltage of the battery bank, and then generate the second differential profile by differentiating the first differential profile with respect to the voltage of the battery bank.

[0113] Next, the processor may diagnoses the state of the battery bank based on the second differential capacity value of the target peak located in a predetermined voltage section among a plurality of peaks of the second differential profile.

[0114] That is, the processor may detect a target peak located in the predetermined voltage section among the plurality of peaks of the second differential profile (S20).

[0115] The voltage section where the target peak is located may be experimentally determined. That is, the voltage section in which the peak where splitting occurs due to uneven deterioration of the battery bank among the peaks of the second differential profile is located may be experimentally confirmed, and the confirmed voltage section may be determined as the voltage section where the target peak is located.

[0116] Then, the processor may diagnose the state of the battery bank by comparing the second differential capacity value ( $Q_p''$ ) of the target peak with a predetermined threshold value ( $Q_r''$ ) (S30).

[0117] For example, the processor may diagnose the state of the battery bank as an abnormal state when the second differential capacity value ( $Q_p''$ ) of the target peak is less than the threshold value ( $Q_r''$ ) (S40). In this case, the abnormal state may mean a state in which the plurality of battery cells forming the battery bank are unevenly deteriorated.

[0118] The threshold value may be the minimum value among the second differential capacity values that the target peak of a normal battery bank may have, or a value determined during the design of the battery assembly.

[0119] In another embodiment, the processor may be configured to diagnose the state of the battery bank as an abnormal state if the second differential capacity value of the target peak is less than a predetermined threshold value and the number of peaks located in the predetermined voltage section exceeds a predetermined reference number. In this case, the abnormal state may mean a state in which the plurality of battery cells forming the battery bank are unevenly deteriorated.

[0120] In another embodiment, the processor may be configured to determine the state of the battery bank based on a plurality of target peaks.

[0121] In this case, the processor may be configured to detect a first target peak located in a first voltage section and a second target peak located in a second voltage section among predetermined voltage sections.

[0122] And, the processor may be configured to determine the state of the battery bank as an abnormal state if the second differential capacity value of the first target peak is less than a predetermined first threshold value and the second differential capacity value of the second target peak is less than a predetermined second threshold value. In this case, the abnormal state may mean a state in which the plurality of battery cells included in the battery bank are unevenly deteriorated.

[0123] In addition, in an embodiment, when the battery assembly to be diagnosed includes a plurality of battery banks, the processor may be configured to generate a plurality of second differential profiles respectively corresponding to the plurality of battery banks.

[0124] In this case, the processor may be configured to diagnose the state of each of the plurality of battery banks as a normal state or an abnormal state based on the plurality of second differential profiles.

[0125] Then, the processor may adjust the charging condition and/or discharging condition of the battery bank according to the diagnosis result for the battery bank (S50).

[0126] For example, when an abnormal battery bank diagnosed as an abnormal state is detected among the plurality of battery banks included in the battery assembly, the processor may be

configured to control a charger that charges the abnormal battery bank to reduce a voltage at the end of charging of the abnormal battery bank or reduce a current rate of a current that charges the abnormal battery bank.

[0127] Also, the processor may be configured to control the cooling device **18** described later to lower the temperature of the abnormal battery bank.

[0128] Meanwhile, the processor may output a visual, auditory or audio-visual notification signal corresponding to the diagnosis result regarding the battery bank using a predetermined output device.

[0129] Then, the processor may repeat the steps described above (S**10** to S**50**) until the battery assembly is no longer in use (S**60**).

[0130] FIG. **11** is a drawing showing a battery pack **10** according to an embodiment of the present disclosure.

[0131] As illustrated in FIG. **11**, the battery pack **10** includes a battery bank BB provided by connecting a plurality of battery cells in parallel with each other, and the apparatus **100** for diagnosing a battery according to the present disclosure. In an embodiment, the battery pack **10** may optionally further include a measurement device **12**, a communication device **14**, a charging/discharging device **16**, and a cooling device **18**.

[0132] The measurement device **12** may be configured to measure the voltage and/or current of the battery bank BB. To this end, the measurement device **12** may include at least one voltage sensor for sensing the voltage of the battery bank BB and/or at least one current sensor for sensing the current of the battery bank BB.

[0133] The measurement device **12** may measure the voltage of the battery bank BB through the first sensing line SL**1** and the second sensing line SL**2**. In addition, the measurement device **12** may measure the current of the battery bank BB through the third sensing line SL**3** connected to the current measurement circuit A. The current measurement circuit A may include a shunt resistor.

[0134] The apparatus **100** for diagnosing a battery assembly according to an embodiment of the present disclosure may obtain voltage values of the battery bank BB through the measurement device **12**. For reference, the capacity of the battery bank BB may be calculated by applying the current integration method to the current charging battery bank BB.

[0135] The communication device **14** may be configured to perform communication with another device located remotely. For example, the communication device **14** may be configured to receive data transmitted from a remote server or communication terminal through a wired and/or wireless communication network and transmit the data to the apparatus **100** for diagnosing a battery assembly, or transmit data generated in the apparatus **100** for diagnosing a battery assembly to another server or communication terminal. To this end, the communication device **14** may include a communication modem that performs wired communication and/or wireless communication.

[0136] The charging/discharging device **16** may be configured to charge and/or discharge the battery bank BB. To this end, the charging/discharging device **16** may include a charger for charging the battery bank BB, a discharger for discharging the battery bank BB, at least one switch for electrically connecting the battery bank BB to terminals T**1**, T**2** of the battery pack **10**, etc.

[0137] The apparatus **100** for diagnosing a battery assembly according to an embodiment of the present disclosure may control the charging/discharging device **16** to perform or stop charging or discharging of the battery bank BB, set charging/discharging conditions, or change the set charging/discharging conditions.

[0138] The cooling device **18** may be configured to cool the battery bank BB. To this end, the cooling device **18** may include a heat sink that absorbs heat from the battery bank BB and releases it to the outside.

[0139] FIG. **12** is a drawing showing a vehicle according to an embodiment of the present disclosure.

[0140] As illustrated in FIG. **12**, the vehicle **2** according to an embodiment of the present disclosure

may include a battery pack **10** that provides electrical energy necessary for the operation of the vehicle and the apparatus **100** for diagnosing a battery according to the present disclosure.

[0141] In this case, the apparatus **100** for diagnosing a battery assembly may be configured to interact with an ECU (Electronic Control Unit) that controls the operation of the vehicle **2** or a BMS (Battery Management System) of the battery pack **10**.

[0142] Additionally, the apparatus **100** for diagnosing a battery assembly may be configured to receive data transmitted from a remote server **4** via a wired and/or wireless communication network, or to transmit data generated by the apparatus **100** for diagnosing a battery to the server **4**.

[0143] For reference, the apparatus **100** for diagnosing a battery assembly according to the present disclosure may be applied to various electrical devices or electrical systems other than vehicles, as well as to ESS (Energy Storage System).

[0144] As described above, embodiments of the present disclosure diagnose the state of the battery bank by using the second differential profile, which represents the relationship between the second differential capacity, which is obtained by taking a second derivative of the capacity of the battery bank included in the battery assembly with respect to the voltage of the battery bank, and the voltage of the battery bank, thereby enabling the diagnosis of the state of the battery assembly including a plurality of battery banks for each battery bank, and improving the accuracy and reliability of the diagnosis result.

[0145] In addition, embodiments of the present disclosure may be capable of accurately diagnosing whether the battery cells are deteriorated unevenly in a battery bank that is provided by connecting the battery cells in parallel with each other by diagnosing the state of the battery bank based on the second differential capacity value of a target peak located in a predetermined voltage section among a plurality of peaks of the second differential profile.

[0146] In addition, embodiments of the present disclosure may perform management of a battery assembly including a plurality of battery banks for each battery bank by controlling the charge and/or discharge conditions of the corresponding battery bank according to the diagnosis result of the battery bank, thereby extending the life of the entire battery assembly and improving safety.

[0147] Furthermore, the embodiments according to the present disclosure may solve various technical problems other than those mentioned in this specification in the corresponding technical field as well as in related technical fields.

[0148] The present disclosure has been described with reference to specific embodiments.

However, those skilled in the art will clearly understand that various modified embodiments can be implemented within the technical scope of the present disclosure. Therefore, the embodiments disclosed above should be considered from an illustrative rather than a restrictive perspective. In other words, the true technical scope of the present disclosure is indicated by the claims, and all differences within the scope equivalent thereto should be interpreted as being included in the present disclosure.

## EXPLANATION OF REFERENCE SIGNS

[0149] **2**: vehicle [0150] **10**: battery pack [0151] **100**: apparatus for diagnosing a battery [0152] **110**: control unit [0153] **112**: second differential profile generating unit [0154] **112**: diagnosing unit [0155] **116**: diagnosis result informing unit [0156] **118**: battery management unit [0157] **120**: communication unit [0158] **130**: input unit [0159] **140**: storage unit [0160] **150**: output unit

## Claims

**1.** A method for diagnosing a battery assembly including a battery bank comprising a plurality of battery cells connected in parallel with each other, the method comprising: generating a second differential profile representing a relationship between a second differential capacity, which is obtained by taking a second derivative of a capacity of the battery bank with respect to a voltage of the battery bank, and the voltage of the battery bank; and detecting a target peak located in a

predetermined voltage section among a plurality of peaks of the second differential profile and diagnosing a state of the battery bank based on a second differential capacity value of the target peak.

**2.** The method for diagnosing the battery assembly according to claim 1, wherein generating the second differential profile includes: repeatedly measuring a voltage value and a current value of the battery bank using at least one electrical sensor while the battery bank is being charged or discharged; and generating the second differential profile using the voltage values and the current values measured while the battery bank is being charged or discharged.

**3.** The method for diagnosing the battery assembly according to claim 1, wherein generating the second differential profile includes; generating a profile representing the relationship between the voltage and the capacity of the battery bank; generating a first differential profile by differentiating the profile with respect to the voltage of the battery bank; and generating the second differential profile by differentiating the first differential profile with respect to the voltage of the battery bank.

**4.** The method for diagnosing the battery assembly according to claim 1, wherein diagnosing the state of the battery bank includes comparing the second differential capacity value of the target peak with a predetermined threshold value, and diagnosing the state of the battery bank as an abnormal state when the second differential capacity value is less than a threshold value.

**5.** The method for diagnosing the battery assembly according to claim 1, wherein diagnosing the state of the battery bank includes diagnosing the state of the battery bank as an abnormal state in which the plurality of battery cells are unevenly deteriorated, when the second differential capacity value of the target peak is less than a predetermined threshold value and a number of peaks located in the predetermined voltage section exceeds a predetermined reference number.

**6.** The method for diagnosing the battery assembly according to claim 1, wherein the battery assembly includes a plurality of battery banks, wherein the method further comprises generating a plurality of second differential profiles respectively corresponding to the plurality of battery banks included in the battery assembly, and diagnosing a state of each of the plurality of battery banks as a normal state or an abnormal state based on the plurality of second differential profiles.

**7.** The method for diagnosing the battery assembly according to claim 1, wherein diagnosing the state of the battery bank includes diagnosing the state of the battery bank as an abnormal state when the second differential capacity value of the target peak is less than a predetermined threshold value, and wherein the method for diagnosing a battery further comprises controlling a charger that charges the battery bank to reduce a voltage at an end of charging of the battery bank or reduce a current rate of a current that charges the battery bank, when the state of the battery bank is diagnosed as an abnormal state.

**8.** An apparatus for diagnosing a battery assembly including a battery bank comprising a plurality of battery cells connected in parallel with each other, the apparatus comprising: a second differential profile generating unit configured to generate a second differential profile representing a relationship between a second differential capacity, which is obtained by taking a second derivative of a capacity of the battery bank with respect to a voltage of the battery bank, and the voltage of the battery bank; and a diagnosing unit configured to detect a target peak located in a predetermined voltage section among a plurality of peaks of the second differential profile and diagnose a state of the battery bank based on a second differential capacity value of the target peak.

**9.** The apparatus for diagnosing the battery assembly according to claim 8, wherein the diagnosing unit is configured to compare the second differential capacity value of the target peak with a predetermined threshold value, and diagnose the state of the battery bank as an abnormal state when the second differential capacity value is less than a threshold value.

**10.** The apparatus for diagnosing the battery assembly according to claim 8, wherein the diagnosing unit is configured to diagnose the state of the battery bank as an abnormal state in which the plurality of battery cells are unevenly deteriorated, when the second differential capacity value of the target peak is less than a predetermined threshold value and a number of peaks located in the

predetermined voltage section exceeds a predetermined reference number.

**11.** The apparatus for diagnosing the battery assembly according to claim 8, wherein the battery assembly includes a plurality of battery banks, wherein the second differential profile generating unit is configured to generate a plurality of second differential profiles respectively corresponding to the plurality of battery banks included in the battery assembly, and wherein the diagnosing unit is configured to diagnose a state of each of the plurality of battery banks as a normal state or an abnormal state based on the plurality of second differential profiles.

**12.** The apparatus for diagnosing the battery assembly according to claim 8, wherein the diagnosing unit is configured to diagnose the state of the battery bank as an abnormal state when the second differential capacity value of the target peak is less than a predetermined threshold value, and wherein the apparatus for diagnosing the battery further comprises a battery management unit configured to control a charger that charges the battery bank to reduce a voltage at an end of charging of the battery bank or reduce a current rate of a current that charges the battery bank, when the state of the battery bank is diagnosed as an abnormal state.

**13.** A battery pack comprising the apparatus for diagnosing the battery assembly according to claim 8.

**14.** A vehicle comprising the apparatus for diagnosing the battery assembly according to claim 8.

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